# FPL 1963

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# ANNUAL REPORT

*of the FOREST PRODUCTS LABORATORY*

FOREST SERVICE / U. S. DEPARTMENT OF AGRICULTURE

# FPL 1963: Annual Report of the Forest Products Laboratory

## FOREWORD

**"a mutuality . . ."**

Over the years, the contacts and exchanges between members of the staff of this Laboratory and our coworkers abroad have been many and fruitful. These exchanges have enriched our understanding of common goals and helped greatly to consolidate our separate experiences and findings. The many evidences of this growing together, as it were, have made plainly apparent a mutuality of interests that during 1963 manifested itself most strongly.

For during 1963 FPL was honored by the gathering here of representatives of two world-wide scientific and technological organizations: Section 41 of the International Union of Forest Research Organizations, and the Fifth Conference on Wood Technology of the United Nations Food and Agriculture Organization. It was the privilege of our staff to act as hosts to the scientists from 32 foreign Nations who came here—many for the first time. To those dedicated scientists, and to that mutuality of interests which they helped make more clearly evident than ever before, it is our pleasure to dedicate this Annual Report.

Among other 1963 highlights were:

- Establishment of two pioneering research units, one in lignin and one in analytical mechanics, that give two distinguished staff members the broadest possible latitude to conduct research.
- A Nationwide symposium on nondestructive testing to bring into clearer focus the potential, as applied to wood, of various possible methods and processes.
- The launching of a southern pine plywood industry, with continuing FPL technical aid, as predicted in the 1962 Annual Report.
- A new research undertaking on the physiology of wood formation.
- Research findings on weathering, solar radiation, and other phenomena of basic significance to wood finishing and stabilization.
- Formation of a new Laboratory-wide committee to coordinate FPL building research.
- Development of a new combination fiberboard–veneer container material named Fiberneer.
- New research on biochemical deterioration of wood.
- Improved pulping and bleaching processes that promise stronger, brighter high-yield pulps and less loss of wood substance.

Numerous other developments outlined in the text of this Report could be included in the above Highlight list. To some readers they may have even greater significance. For further details, your attention is directed to the appended list of 1963 publications.

Edward G. Locke

EDWARD G. LOCKE
*Director*

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**At speaker's table on opening day of the FAO Conference on Wood Technology were, from left, A. D. Freas, assistant to the Director of FPL and arrangements chairman for the IUFRO–FAO meetings; John A. Yavorsky, Chief, FAO's Wood Technology and Utilization Section; FPL Director Edward G. Locke, Conference chairman; Harold A. Vogel, North American representative, FAO; Edward P. Cliff, Chief, U.S. Forest Service; and Roman Parewicz, FAO Forestry Officer.**

# INTRODUCTION

Among the diversified activities of the FPL staff during 1963, the predominant highlight was its role as host to two international organizations devoted to forest products research and its technological applications. It was the first time that either group had met here, although FPL staff members have been active in both for many years. Significantly, it was also the first time that both of these complementary organizations had met at the same place anywhere on successive dates.

Section 41, Forest Products, of the International Union of Forest Research Organizations convened at FPL September 11–13. During the following 2 weeks, September 16–27, the Fifth Conference on Wood Technology of the United Nations Food and Agriculture Organization met under joint sponsorship of the U. S. Department of Agriculture and the State Department. Some 60 delegates of 32 foreign Nations participated in one or both.

IUFRO is an independent association with membership open to both governmental and privately operated research units. Its main purpose is to foster exchange of information and closer relationships between scientists with common interests and problems.

The FAO conference, on the other hand, was an official meeting of delegates representing the participating Nations. A number of U. S. industrial concerns, educational institutions and laboratories sent observers to participate in discussions. It was the first such conference held in the United States since FAO's Forestry and Forest Products Division was formed at Washington, D. C., in 1946. All four previous ones have been in Europe. Their purpose is to gather scientific and technological information and make it available to UN member Nations to help them develop their timber resources.

The IUFRO Section 41 meeting was devoted to technical and scientific papers presented by three work-

**Speaking for African Nations at the official U.S. State Department reception and dinner for FAO delegates was Lawrence Okigbo of the Department of Forest Research, Ibadan, Nigeria.**

**The unique forest utilization problems of New Zealand were told to the IUFRO conference by J. S. Reid, in charge of research of that British Dominion's Forest Service.**

ing groups, wood quality, sawing and machining, and performance of wood in fire. At the concluding session, it was decided to study the advisability of organizing a fourth working group, in wood chemistry. At the concluding session, Dr. V. L. Harper, IUFRO Vice President and deputy chief of the Forest Service in charge of research, spoke on the complementary roles of IUFRO and FAO in research and technology.

Edward P. Cliff, chief of the Forest Service, welcomed delegates to the FAO Conference on the opening day as official United States Government representative. Speaking for FAO Director–General B. R. Sen and Dr. N. Osara, director of FAO's Forestry and Forest Products Division, was Harold A. Vogel, North American representative of FAO. FPL Director Locke was elected permanent Conference chairman. Vice chairmen were Dr. Jean Collardet, director of the French Technical Center for Wood at Paris, and Dr. Eugenio de la Cruz, retired director of the Philippine Forest Products Research Institute. L. J. Markwardt, retired FPL assistant director and long active in FAO forest products work, was elected honorary vice chairman.

Conference working parties functioned in the areas of plywood; fire behavior of wood and wood-base materials; mechanical properties of wood; physical problems of wood and wood-base materials; testing methods for fiberboards and particle boards; sawing and machining; structural grading; and wood preservation. The Conference took initial steps toward setting up a working party on building and construction.

Proceedings of the Conference will be published by FAO from its Rome, Italy, headquarters.

Director Locke also served as official United States delegate to an FAO International Consultation on Plywood and Panel Products held in Rome during July. From there he went to Turku, Finland, to report on activities of IUFRO Section 41, of which he is chairman, at a meeting of IUFRO officials. Serving as technical consultant and a member of the Plywood Consultation Secretariat in Rome was Wayne C. Lewis, in charge of FPL fiberboard research; Dr. H. O. Fleischer, chief of FPL's division of Solid Wood Products Research, also attended.

Another major meeting at FPL during 1963 that attracted international attention on an informal basis was a pioneering Symposium on Nondestructive Testing October 7–9, conducted in cooperation with the National Lumber Manufacturers Association. A number of FAO Conference delegates stayed over for the symposium. Speakers included specialists in research on nondestructive testing of metals, plastics, and other materials as well as wood products. Stimulated by the results and discussions, those attending voted to recommend that another be held within a year.

As usual, many smaller meetings were held at FPL during the year—most of them concerned with industry problems and research needs. Prominent among these were conferences dealing with technical problems confronting the new southern pine plywood industry and new size and moisture content standards for softwood lumber.

**Individual radios tuned to one of three official languages, FAO delegates listened to instantaneous translations of talks in English, Spanish, and French by U.S. State Department experts.**

Work also proceeded on the planning of a new addition to FPL, designed to facilitate new and expanded research on wood fiber products and wood chemistry. Funds to engage architects for such planning had been made available by the Congress.

As the national center of the Forest Service for forest products research, FPL also exchanges aid and counsel with utilization research units of 10 regional Forest Experiment Stations. These units bring to industry results of FPL research, keep FPL informed of developments, conduct applied research, and cooperate with other agencies in work on local problems.

As a matter of practical management efficiency, the work of FPL is divided among five research areas: wood quality, wood engineering, wood chemistry, solid wood products, and wood fiber products. In this Annual Report, the same organization pattern is adhered to in general.

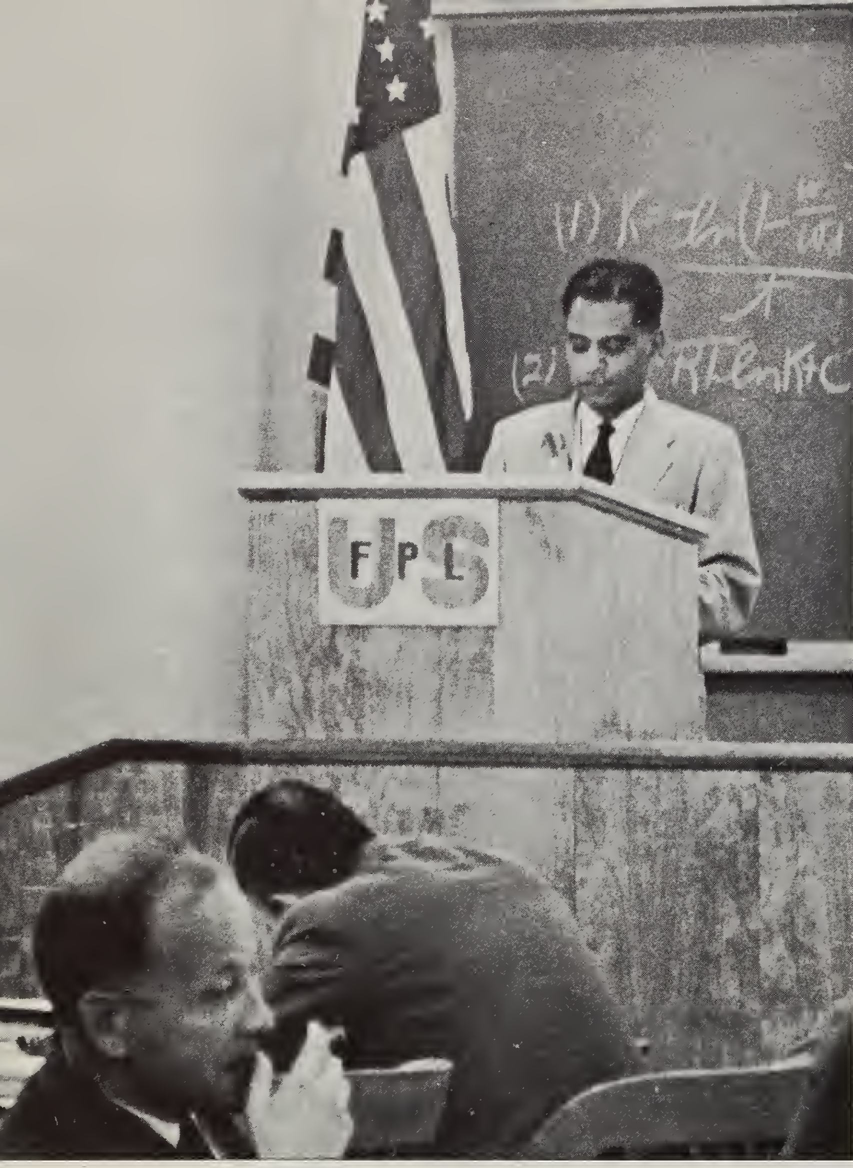
One of the marked advantages of a centralized Laboratory is the presence and constant availability of a staff trained in many skills and scientific disciplines. Consequently, there is much cross feeding of information and ideas between divisional and smaller research units of FPL. Engineers consult with chemists, pathologists with entomologists, physicists with wood anatomists, and so on. The conventional compartmentation of science is being constantly breached in this way to bring the various spheres of basic knowledge directly to bear on research problems.

During 1963, administrative action was taken to stimulate this type of cross-feeding and thus accelerate progress in a major area of FPL research. A Committee on Building Research was appointed which meets periodically and critically appraises FPL work and current industry trends in the general field. Committee members represent all major areas of FPL research related to structures, with emphasis on housing.

As a starting point, the committee defined its scope of operations as follows:

> To continually review and coordinate research and development studies of products, processes, and systems for wider and more intelligent use of wood and wood-base materials in the building industry.
>
> To suggest and recommend areas for new efforts needed as a part of the Laboratory's research and development program.
>
> To consider various means to provide more effective dissemination and application of research results in order to encourage the wider practical utilization of these findings by the building industry.

Reviewing FPL research in the field, the committee noted that 13 studies have recently been completed and 76 are currently under way in five major areas, for a total of 89. Research areas included are those concerning environment and conditions of use; improved protection from decay, insects, fire, and the elements;



development of new materials; improved design procedures; and building components and new building techniques.

The committee discussed plans for a small structure to be built in 1964 for the purpose of housing instrumentation for exposure studies on various building materials at the Madison exposure site. It was agreed that this building could simultaneously be utilized as a demonstration and evaluation structure for new materials, structural elements, and systems under study at present.

As a longer range objective, the committee is also considering remodeling of a section of the present main building as a structural research laboratory. Facilities would be installed to permit putting full-size structures under various types of loading to determine strength, rigidity, and related properties.

A resume of major research highlights of 1963 follows.

**Critical wood preservation problems of subtropical India were described to IUFRO by Dr. A. Purushotham, wood preservation officer, Forest Research Institute, Dehra Dun.**

**Architectural Engineer L. O. Anderson demonstrates concept in panelized wall construction to other members of a new FPL building research committee. Left to right around table are John M. Black, in charge of finishing research; Lyman W. Wood, in charge of structures research; Anderson; Committee Chairman W. G. Youngquist; Edward W. Kuenzi, in charge of design criteria research; H. W. Eickner, in charge of fire research; Robert A. Hann, in charge of environmental effects research; and Richard F. Blomquist, in charge of adhesives research. Absent from the meeting was O. C. Heyer, architectural engineer.**

# WOOD ENGINEERING RESEARCH

In this period of rapidly advancing technology, continued large-scale structural use of wood is dependent on adequate research and developmental work to keep abreast of advances with other materials. A basic purpose of FPL engineering research is to provide industry with more precise knowledge of (1) the basic strength properties of lumber, plywood, fiberboard and particle board, laminated wood, and composites of wood, paper, metal, plastic, and other materials; (2) methods of engineering analysis and development of design criteria for wood and fastenings; and (3) new and improved structural systems. Attainment of these objectives calls for comprehensive research, both basic and applied, including pilot-scale investigations.

### Basic Engineering Properties

The swath of devastation cut by Hurricane Frieda in the forests of Oregon and Washington in October 1962 left salvage problems for science as well as industry. Not all of the damage was visible in the form of uprooted and shattered trees. Some timber, standing as well as fallen, sustained internal injuries such as compression failures—fine, irregular cracks in the wood that seriously weaken it for some uses. A study of the influence of these easily overlooked fissures is under way at FPL, initially on pole timbers, so that the needed adjustments in transmission line design can be made by utility engineers.

The basic study of the strength and related properties of white fir *Abies concolor*, noted in the 1962 Annual Report for green wood, was concluded with evaluations of air-dry material (12 percent moisture content). It was found that the average modulus of elasticity, an indicator of stiffness, for the dry material was about 4 percent higher than that of material evaluated some years before. (For green material the figure is 6 percent.) This is not considered enough to affect materially the rating of *Abies concolor* among other species of the commercial white fir group, since it is substantially lower in stiffness than the others. Stiffness is a key property in joists, rafters, and similar structural elements. In shear strength parallel to the grain, the air-dry material was about one-third higher than that evaluated earlier.

Green wood of Hawaii-grown Nepal alder *(Alnus Nepalensis)* was found to be generally comparable to wood of the same species grown in India. The wood is appreciably below red alder, a western U. S. species, in specific gravity, shrinkage, and flexure, but comparable with it in hardness. Research on this species is part of a survey of Hawaiian woods designed to evaluate them for furniture and cabinet use.

Engineering studies of information produced by the density survey of western woods, as reported under Wood Quality Research, were continued in collaboration with an industry Western Woods Technical Committee. The Committee has proposed an interpretation procedure that is being evaluated.

Basically, the procedure involves regression sampling, in which a property such as specific gravity, which is determined directly from the core samples taken from many thousands of trees, is mathematically related to strength and stiffness. Computer programs have been set up for making such determinations. Work was concentrated first on Douglas-fir samples from various parts of its growth range, which extends from the Pacific Northwest to New Mexico.

What happens to wood when it is loaded beyond its proportional limit—the point beyond which it no longer returns to its original size or shape when unloaded—is not well understood. The deformation that results is ascribed to rheologic behavior common to all materials that have a proportional or elastic limit. They exhibit certain flow and elastic properties well before actual failure occurs under maximum load.

A study of these socalled viscoelastic properties of wood under perpendicular-to-grain loading has provided a means of describing its rheologic behavior in terms of the creep function of linear viscoelastic theory. Elastic compliance appeared to have the same magnitude in tension and compression. Flow compliance, however, was twice as great in compression as in tension at any given time during the loading cycle. A linear relationship appears to exist between strain and stress up to at least 60 percent of the ultimate static strength.

### Effects of Chemical Treatments on Strength

When wood is treated with fire-retardant chemicals, certain physical and mechanical changes are known to occur. The nature and extent of these changes are under FPL investigation.

The current approach to this research involves a basic study of the physical and mechanical properties of small clear specimens of a typical softwood, ponderosa pine, and a typical hardwood, red oak, when treated with solutions of individual chemicals that are used in fire-retardant formulations. Preliminary results indicate that the salts differ markedly in their effects on wood properties.

The immediate effect on strength appears to be related to the physical presence of the chemical in the wood, the hygroscopicity of the chemical, and the degree to which the chemicals penetrate the cell walls of the wood. Individual chemicals differ considerably in

all of these factors and thus produce widely different immediate effects on strength, moisture content, and swelling characteristics.

Loss of strength in aging was accelerated by an acid salt but not by an alkaline salt. The aging effect is apparently related to the extent and nature of chemical degradation produced by the chemical solution.

This study of fire-retardant effects is being conducted in cooperation with the National Lumber Manufacturers Association, the American Wood-Preservers' Association, and the American Institute of Timber Construction to facilitate use of treated wood products.

### Drying Stresses in Wood

A computer-programmed analysis of extensive stress data obtained on red oak boards during the early stages of drying has made it possible to assign definite stress values to various parts of a board being dried, rather than the crude relative values previously obtainable. The analysis is continuing on data for the later stages of drying, and procedures are being considered for relating the stress values obtained to strength properties. Purpose of this work is to make it possible to determine temperature and humidity conditions that achieve drying at the fastest practical rate without developing stresses great enough to cause serious drying degrade, such as honeycomb, collapse, and splitting.

A similar analysis was made of the results of a study of immediate temperature and moisture content effects on the perpendicular-to-grain mechanical properties of ponderosa pine. Modulus of elasticity was found to be about the same in both tension and compression for comparable temperature and moisture content conditions; it was much lower in specimens with growth rings at 45° to the loaded surface than in those at 0° (flat grained), and highest at 90° (vertical grained). Maximum tensile stress, on the other hand, was highest in specimens with rings at 90°, intermediate at 45°, and lowest at 0°. Deformation to failure was three or four times as great in specimens with rings at 45° as those with rings at either 0° or 90°, probably because shearing strain was greater.

### Nondestructive Testing

Mounting industrial as well as research interest in methods and techniques for nondestructive testing of wood to determine its strength and related properties without damaging it was clearly evident at a symposium on the subject held at FPL October 7–9, 1963, in cooperation with the National Lumber Manufacturers Association. Some 100 representatives of industry, universities, and other research institutions heard specialists in various branches of the subject.

Nondestructive testing methods developed for other materials as well as wood were examined and research possibilities outlined. A recommendation was adopted that representatives of all branches of the wood industry meet in April or May of 1964 at FPL to define more clearly the needs for nondestructive test methods, and that another symposium built around those needs be held later in the year.

FPL research on nondestructive testing methods during 1963 emphasized studies of vibration characteristics and the interaction of radiation with wood.

Vibration experiments with clear Douglas-fir specimens 2 by 2 by 40 inches in size over a moisture content range from 2 to 28 percent indicated that either dynamic or static modulus of elasticity can be used to estimate modulus of rupture in flexure and maximum crushing strength parallel to grain. Correlations were generally best in the moisture content range of 12 to 20 percent. Shear and toughness did not correlate well with vibrational characteristics.

Experiments with air-dry white fir 2 by 4's of No. 2 Common grade and redwood 3 by 8's of very low quality indicated that even large numbers of such strength-reducing characteristics as knots do not interfere seriously with estimates of modulus of rupture from either static or dynamic modulus of elasticity as determined by vibrational characteristics. Correlation of modulus of rupture with specific gravity was poor, however, especially for the redwood beams.

Gamma radiation may prove to be a useful tool in nondestructive testing. Experimental data indicate that suitable placement and shielding of the radiation source and detector make possible a consistent, approximately linear relationship between backscatter count and density of the material under test. Research is being continued to evaluate such related effects as those of wood structure, moisture content, and thickness, all of which may have a bearing on the effectiveness of penetrating radiation techniques.

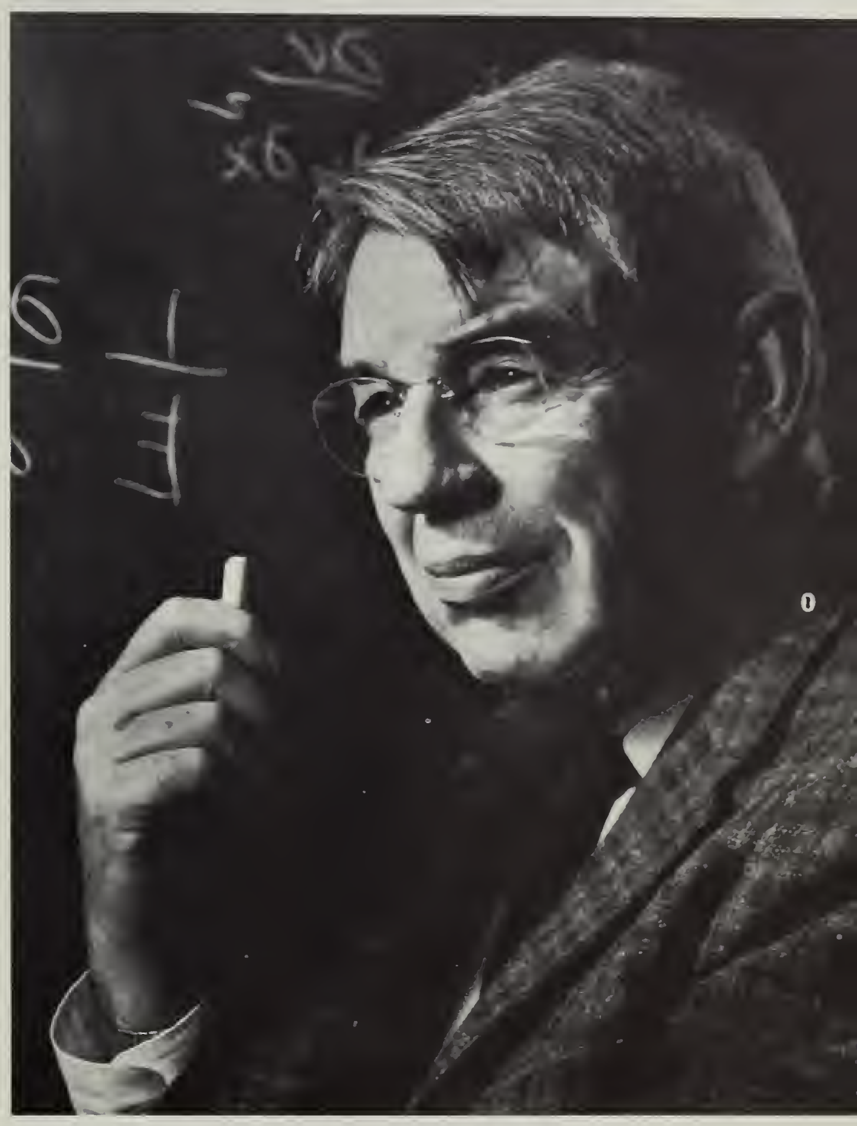
### Fiberboard Properties

The steadily increasing use of building fiberboards of various densities, as well as of particle board, focuses attention of manufacturers and users alike on the need for better definition of the basic engineering properties of these materials. In cooperation with the American Hardboard Association, FPL is well along in an extensive evaluation of hardboards furnished by all 11 major manufacturers in the United States.

During 1963, more than 5,000 specimens were evaluated to obtain data on flexure, tension, and compression at normal temperature and humidity conditions. With new techniques developed for the purpose, shear is also being evaluated. Effects of rate of loading and moisture content on deformation and strength are to be ascertained later. Typical insulation boards, medium density building fiberboards, and particle boards will be included.

The building fiberboards, ranging from 30 to 50 pounds per cubic foot in density, are becoming popular for house siding. In 1962, four manufacturers entered the market, which until then was being supplied by two. FPL has assisted them and FHA with comparisons and evaluations in the development and final product stages.

The insulating value of these materials is also being assessed in studies designed to relate thermal conductance to specific gravity. To expedite and cut the cost of such studies, FPL has reinstrumented and automated its guarded hot-plate equipment.



**Charles B. Norris, engineer in charge of new pioneering unit in analytical mechanics.**

#### Pioneer Research Unit in Mechanics

The basic importance of developing new and more refined engineering theories concerning wood as a structural material was recognized in 1963 by the U. S. Department of Agriculture with the establishment of a pioneering research unit in analytical mechanics at FPL. Heading this unit is a long-time member of the Wood Engineering Research staff, C. B. Norris. Work of the unit is centered on exploration of fundamental aspects of timber mechanics without specific objectives. The unit is assigned to do basic research that is not problem oriented. Only brief, pertinent annual statements about research in progress are necessary.

Research in this unit is concerned with theoretical considerations and use of analytical mechanics techniques for interpreting experimental data. One study, for example, involves the behavior of wood under stress to develop a better understanding of the mechanism of failure. Ultimately, it is hoped to establish more efficient design criteria for engineers charged with the planning of structures.

A theory of orthotropic elasticity based on average mechanical properties and infinitesimal calculus has been studied for application to the problem. Better correlation with experimental findings appears likely, however, with respect to wood, especially where problems of localized stress concentrations are concerned, when the calculus of finite differences is used.

An analysis of radial tension stresses in curved laminated beams, the occurrence of which is not well understood, was made using the theory of orthotropic elasticity. The immediate object was to check on the stress values obtained by a more elementary method long in general use, but about which some doubts have been raised by practical experience. While generally confirming the older theory, the new analytical approach indicated that radial tensile strength is reduced when a bending stress is present—as is generally the case in use of such beams. The significance of this finding with respect to general design theory is being studied.

A theoretical analysis was made of the probable bending behavior of a number of thin metallic sheets bonded together with a resin adhesive, as part of cooperative research for the Air Force Aeronautical Systems Division. Results of the theory are being checked experimentally. This study has potential application to wood in that it may lead to better understanding of the part played by the annual rings in distributing stresses.

#### Nose Fairing for Polaris Missile

Design criteria developed generally for plywood shell structures under combined loading conditions proved of great usefulness to FPL engineers in designing a nose fairing for the Polaris A-3 missile, now in successful use by the Navy as a weapon launched from submerged submarines. The work was done in cooperation with the Office of Naval Research.

**Nose fairing designed, on basis of FPL plywood design criteria, for Navy's Polaris A-3 missile.**

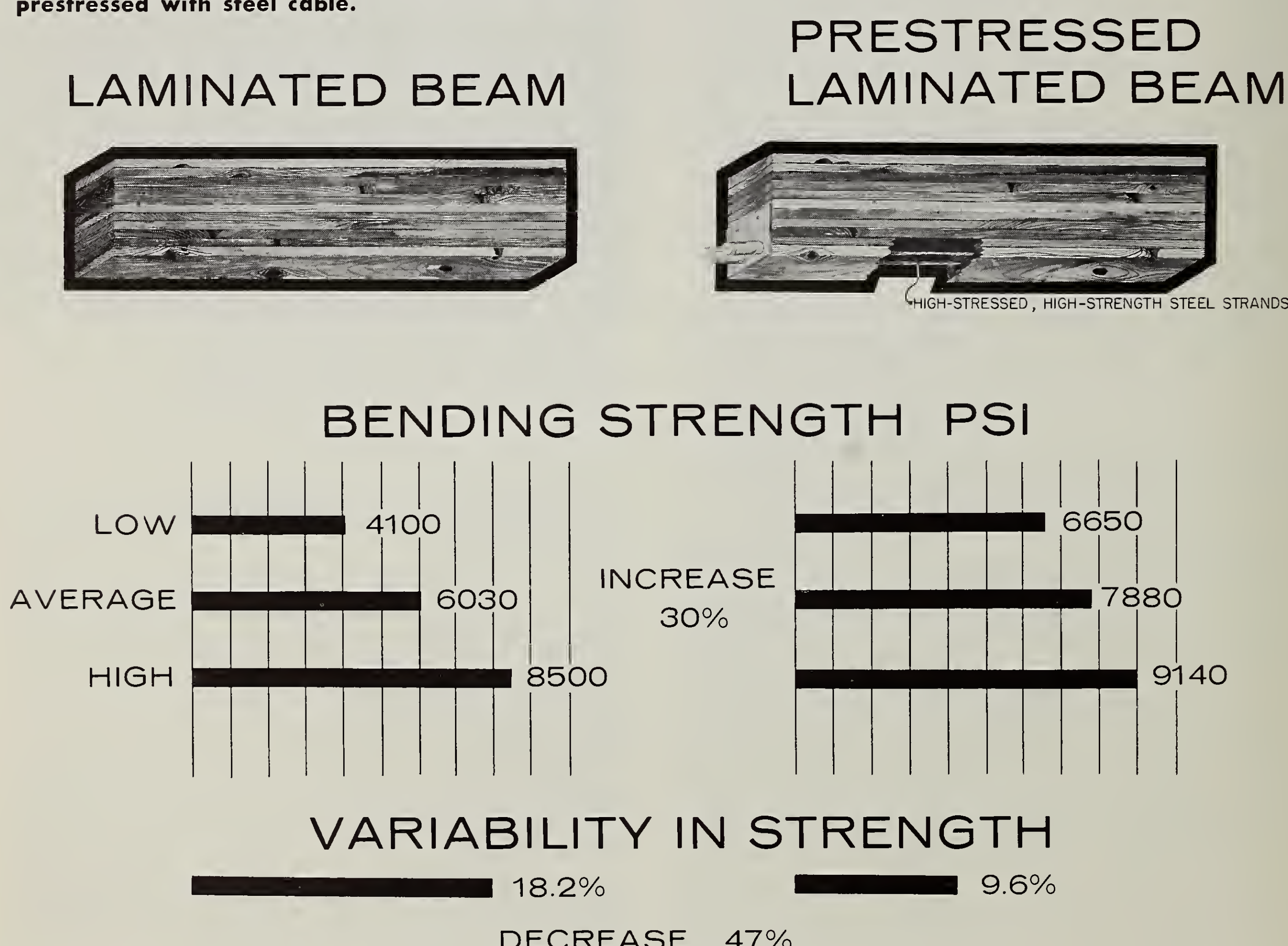
Plywood was chosen because of its low weight for its stiffness and strength and because of its marked superiority to high-strength metals and plastics in resistance to crack propagation. The nose fairing is approximately 6 feet long by 5 feet in diameter at the large end and 2 feet at the small end. It has been established as standard for this missile; several successful launchings have proved out the design.

### Laminated Construction Criteria

Research to increase the load-bearing capacity of laminated beams by prestressing them with steel cable, as described in the 1962 Annual Report, continued to yield promising results in 1963.

When beams fabricated of relatively low-grade lumber were prestressed with cable, bending strength was increased by about 30 percent. Moreover, variability between beams was reduced by one-half. It is considered probable, therefore, that if long-time loading studies confirm these findings, higher design stresses may be permissible and the use of lower grade material expanded for such structural members.

**Higher bending strength, less variability add up to greater design efficiency for laminated beams prestressed with steel cable.**



Meantime, another method of prestressing, by bonding a layer of high-strength steel to the tension side of the beam, is being investigated.

More suitable design concepts for tapered laminated beams—deeper at one end than the other or in the center than at either end—are indicated from a combined theoretical analysis and experimental evaluation of such beams. Further studies are being made to get more precise criteria for modifying the depth of such beams for required loadings.

Publication of Commercial Standard CS 253–63 for structural glued laminated lumber by the U. S. Department of Commerce capped 4 years of close cooperation between the laminating industry and FPL personnel to make possible this reliable guide to technological efficiency for manufacturers. The standard and the certified inspection procedures that accompany it are expected to enhance the status of wood as an engineering material and assure greater consumer satisfaction and more serviceable products.

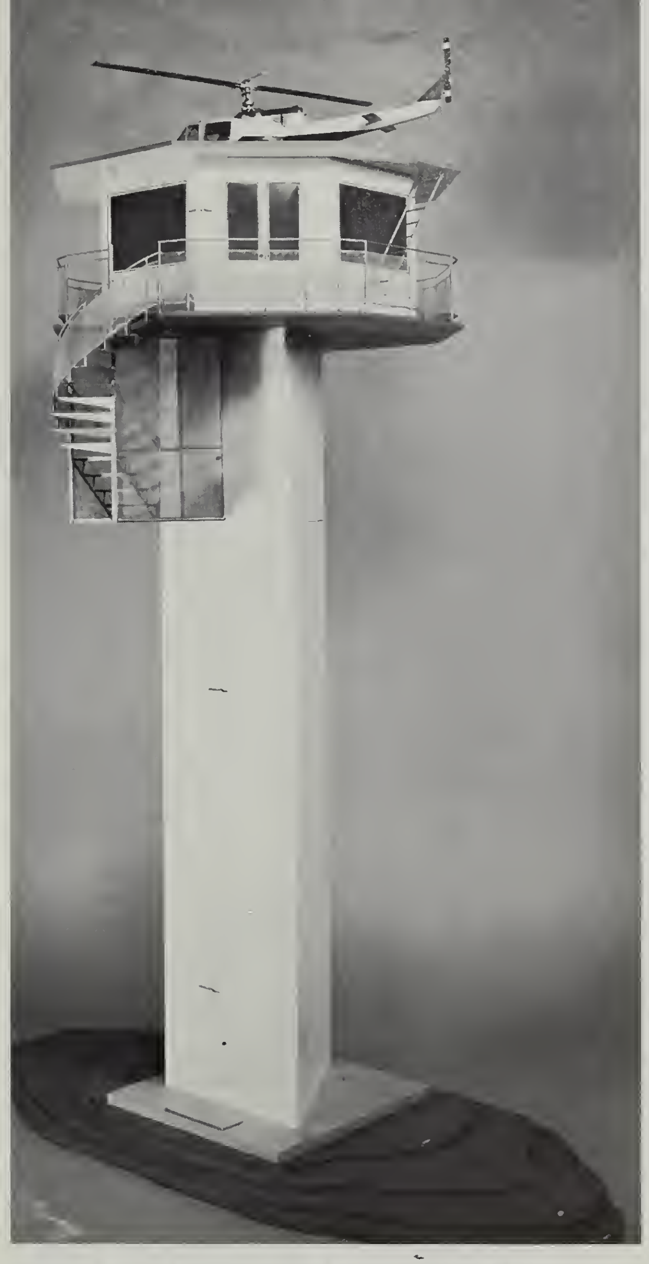
An example of continuing guidance given the laminating industry to help assure product quality was the development of relatively simple procedures on which manufacturers can base quality-control requirements for end joints used to bond boards in a single layer, or lamination, together end to end. The recommendations cover both scarf joints and finger joints of various designs.

### Sandwich Fire Lookout Tower

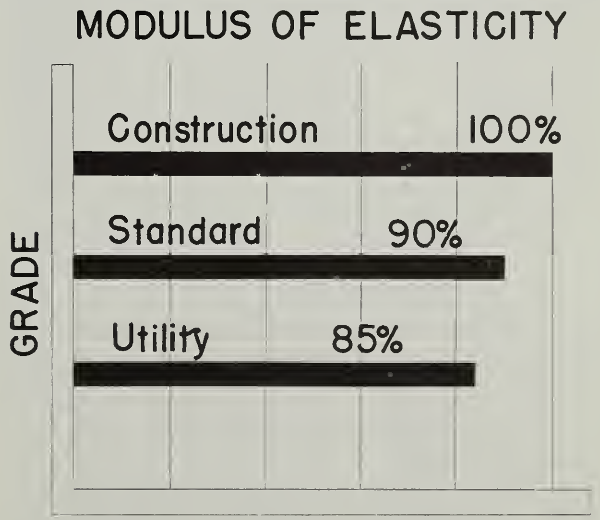
The potential inherent in sandwich construction was dramatically illustrated when FPL design research engineers collaborated with a West Coast aircraft builder to show how paper and plywood could be combined to build a radically different type of fire lookout tower for use in forests. Models of two designs, one with a cylindrical center column and the other with one of triangular shape, were built. The inherent light weight and great stiffness and strength of sandwich construction open new possibilities for erection of such towers at points inaccessible for conventionally built ones. The sandwich construction used consisted of honeycomb cores of paper resin-treated for water resistance and faced with plywood.

### Structural Investigations

In no area has the use of wood been more vigorously challenged in recent years by producers of other materials than in the construction field. FPL research is aimed at developing new ways to use wood in structures of all types, from light-frame temporary buildings to permanent ones built for heavy-duty commercial and industrial uses. In housing, of course, are found the greatest markets for wood products, and FPL research in this field is being given renewed impetus.



**Model of sandwich fire lookout tower with triangular column enclosing elevator or staircase.**




**Comparative modulus of elasticity of three grades of softwood dimension lumber widely used in construction.**

**FPL workmen assemble roof truss of unique double-chord design originated in research on more efficient housing components. Truss is proposed for 4-foot rather than conventional 2-foot spacing. Elements are assembled by gluing them to plywood gussets, spacers, and center post.**

Under investigation is a new system of house wall and roof framing, along with modified interior and exterior covering materials. Included are a modified post-and-beam load-bearing wall, prefinished exterior panels combining siding and sheathing, modified combinations of materials for interior coverings, more widely spaced and economical roof trusses, and a combination structural and weather-resistant roof covering. Research is now in the stage of determining experimentally the performance of the various system components as a check on design criteria.

Published findings from several institutions conducting research on roof trusses generally deal with initial performance—that is, strength and rigidity under short-time loads. In use, of course, such structural elements must support long-continued loads and withstand other stresses that can vary markedly with the seasons or use conditions. A long-time investigation of wood-truss durability is being conducted.

Being evaluated are such service factors as moisture content changes, temperature effects, creep (permanent sag or other deformation) under long-continued load, cyclic loading effects, joint geometry, and exposure evaluations. Nailed, glued, and metal truss-plate joints are included in the moisture-cycling studies. Early results indicate that rigidity is affected more than strength, and that glued joints are affected more than mechanical joints. This series of evaluations will continue for several years.

Pole framework designs for farm and light commercial buildings have become increasingly popular in recent years. So used, poles anchored in the ground are stressed differently than utility line poles, which are critically loaded at the groundline. In building frames, the critical stresses may occur higher up.

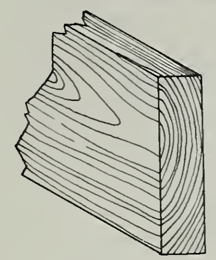
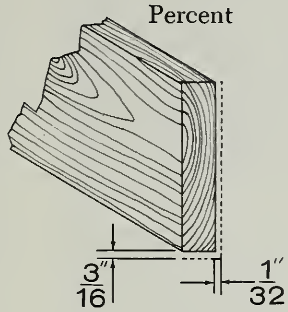
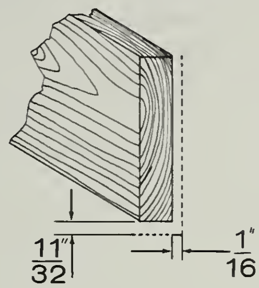
To aid designers of such buildings, FPL engineers have studied the distribution of moments and forces along the length of poles as used in several typical building designs. Effects of spiral grain on pole strength have also been studied. Further research appears needed, especially on use of poles in hurricane-resistant construction and in areas with unstable soil conditions.

Revisions of sizes and grades of softwood lumber in the American Lumber Standards promulgated by the U. S. Department of Commerce for general industry acceptance involved technical guidance by FPL. Work on the establishment of new sizes based on moisture content is referred to under Solid Wood Products Research. On the matter of grade standards, technical advice has been furnished the American Lumber Standards Committee on proposed groupings of species and grades in simplified joist and rafter span tables.

FPL has given technical advice and guidance to two commercial developers of mechanical lumber stress-rating machines. Cooperation is also being given the Federal Housing Administration in a study of strength and stiffness of production samples of machine-graded lumber.

Data on maximum temperatures occurring in walls and roofs of houses in Tucson, Ariz., Athens, Ga., Portland, Oreg., Diboll, Tex., and Madison, Wis., were analyzed. Results show that wall temperatures may occasionally go above 130° F. and roof temperatures above 160° F. These findings have significance in setting up durability requirements for adhesives used to fabricate wall and roof components.

**Changes in dimensions, stiffness of 2 by 10 joists when dried**

| | Green | Dry | |
|---|---|---|---|
| | Percent | Percent | Percent |
| |  |  |  |
| Moisture content | 75 | 17 | 11 |
| Size | 100 | 98 | 96.5 |
| Modulus of elasticity | 100 | 110 | 120 |
| Stiffness | 100 | 100 | 102 |

### Packaging Research

The packaging industry, now rated sixth largest in the Nation with products and services valued at $23.5 billion annually, consumes great quantities of wood products. Low-grade lumber finds some of its best markets in boxes, crates, and pallets. More than one-half of all paper and paperboard goes into 124 billion containers and immense amounts of cushioning, wrappings, and other packaging materials. Metals, plastics, films, foams, and other materials are strongly challenging wood products in many packaging uses, however, and thereby creating more urgent needs for research.

A new FPL-developed container material called Fiberneer, resembling single-wall corrugated container board but consisting of paper-overlaid veneer facings on both sides of the corrugated sheet, shows high promise as a lightweight, moisture-resistant container board with excellent stacking strength. Extensible kraft paper is used for the overlays. Pilot-plant experiments at commercial board mills indicate it can be made on high-speed machinery and scored for future folding into boxes.


**More graphically than any test machine, these FPL staffers demonstrate the superior stacking strength of a Fiberneer box, which supports Technician John D. Wiese (260 pounds), while domestic fiberboard box quickly collapses under Electronics Engineer William D. Godshall (109 pounds). Both boxes had been conditioned to 97 percent relative humidity and 80°F.**

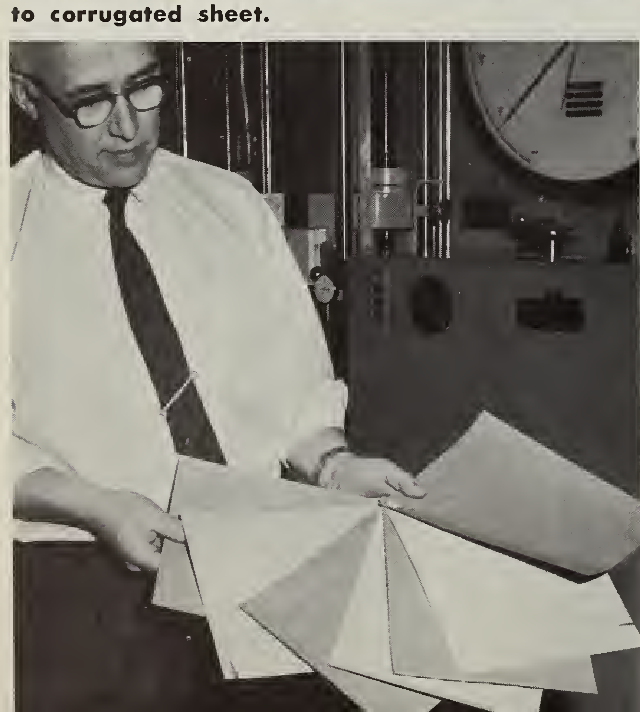
Fiberneer's remarkable top-to-bottom compressive strength approaches that of the best triple-wall material, yet it is lighter and only one-half as thick. Better than average performance was experimentally obtained under conditions of high humidity. Boxes made of it are being evaluated for resistance to rough handling and for compressive strength after storage in a normal dry atmosphere, a highly humid one, and possibly water immersion. This work is being done in cooperation with the Air Force, and if performance evaluations warrant, a material specification will be prepared for Air Force consideration.

Completion of work on double-wall fiberboard containers discussed in the 1962 Annual Report has resulted in a recommendation that present freight classification load limits for this type of container be increased. Specifically, the petition, submitted by the Fibre Box Association, recommends that Rule 41 of the Uniform Freight Classification be modified to permit gross weight limits of 225 pounds instead of 140 pounds for containers made of 500-pound-test double-wall and of 250 instead of 160 pounds for those of 600-pound-test double-wall.

A new evaluation method was devised as an aid in determining the top-to-bottom compressive strength of a fiberboard box. A short-column specimen was devised, and experimental values obtained with it were found to correlate well with theoretical values for corrugated fiberboard. Studies are being continued to establish a relationship between top-to-bottom compressive strength and stacking strength to permit predicting, from properties of the component paperboards, the stacking strength of a container.

Chemical treatments designed to improve the moisture resistance of corrugated fiberboard and thereby prevent loss of compressive strength in containers exposed to high humidity, were evaluated under normal, highly humid, and wet conditions. The treatments had been devised and applied by FPL pulp and paper specialists to paper used in these experiments. Preliminary results indicate that substantial improvement can be attained. The best treatment resulted in containers almost as strong under compressive load when exposed to 80° F. and 90 percent relative humidity as were untreated containers exposed to the relatively dry condition of 73° F. and 50 percent relative humidity.

**Engineer Robert S. Kurtenacker shows construction of Fiberneer under evaluation for container uses. Kraft liners are glued to both sides of each sheet of veneer, then the two composites are glued to corrugated sheet.**



### Pallets

Evaluation was continued of pallets specially designed for use with new automated loading systems for cans, in cooperation with the Can Manufacturers Institute. A particularly promising design, called the "picture frame" pallet, has four perimeter deck boards mitered together at the corners. It has proved decidedly superior in rough-handling performance.

Six western species little used for pallets are being evaluated in comparison with Douglas-fir, the species strongly preferred by West Coast users. Western hemlock, western larch, and ponderosa pine are the softwoods being compared for performance along with the hardwoods red alder, black cottonwood, and tanoak.

The excellent experimental performance of pallets made of aspen, a lightweight wood plentiful in the Northeast, Lake States, and Rocky Mountains but little used as lumber, was described in the 1962 Annual Report. During 1963, FPL findings were presented to various groups and individuals, including a meeting on "Action for Aspen" at Colorado State University, Fort Collins. Since then at least one major West Coast pallet manufacturer has switched to aspen grown in the Colorado Rocky Mountains, and several Lake States producers have begun to use the species.

### Container Fastenings and Joints

As in other types of construction, automation of assembly operations, notably installation of fastenings, is getting much attention among producers of containers and pallets. The comparative strength of joints made by various means and with new kinds of fastenings is being investigated by FPL packaging engineers as a guide to interested manufacturers. Evaluation methods include shock and vibration loads as well as static loads, hence withdrawal resistance is of key importance.

Recent investigations indicate that nylon-coated staples and helically threaded nails have remarkable resistance to withdrawal loads even after severe exposure conditions. Common nails and socalled T-nails etched with acid or coated with epoxy resin, on the other hand, lost considerable holding power even after short exposure to the same conditions.

# WOOD FIBER PRODUCTS RESEARCH

With consumption rising year by year, pulp and paper products account for a steadily larger proportion of the annual cut of timber; current estimates put it at about 25 percent. Per capita consumption is now greater than 450 pounds a year and projected for continued gains despite a rising population and mounting competition from other materials. By any economic test, in terms of timber markets, or jobs, or national income, or production of needed goods, or fulfillment of consumer demands, the pulp and paper industry is of key importance to the Nation.

FPL research in wood fiber products is very largely concentrated on pulp and paper. Its program is designed to contribute to more efficient utilization of wood through constant improvement of pulping and papermaking processes. During 1963, this program was carried forward through research on more efficient pulping and bleaching processes, procedures for making stiffer and more dimensionally stable papers, and basic studies of fiber bonding and paper sheet formation to attain better understanding and control of fundamental properties from an engineering standpoint.

**Pulping Processes**

FPL research on pulping processes has a two-fold objective: to gain greater efficiency through increased yield of better pulps and to devise economical procedures for curtailing or eliminating stream-polluting effluents. During 1963, important light was shed on the chemistry of the polysulfide process, and the advantages of sulfite pulping were enhanced by a development that promises more tear-resistant pulps.

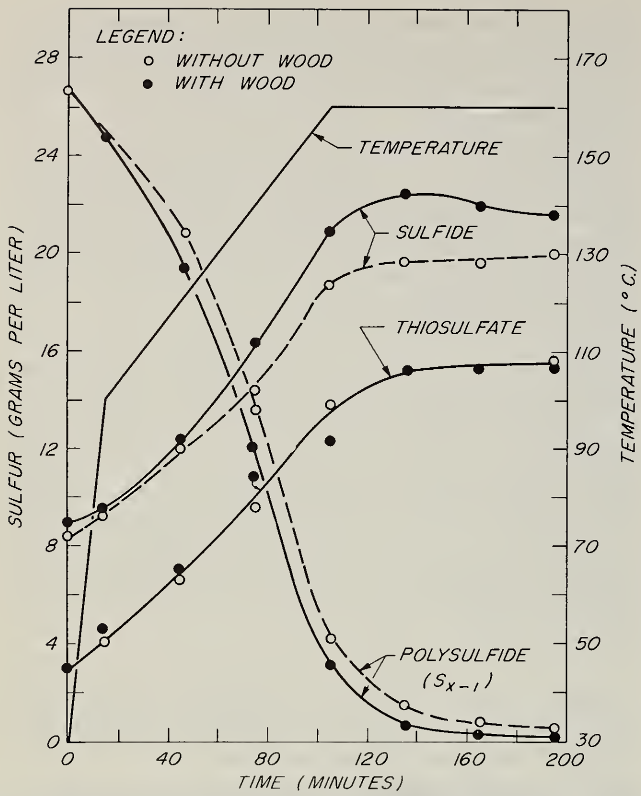
*Polysulfide Pulping.*—Completion of research on the basic chemical reactions involved in the polysulfide process has demonstrated the technical feasibility of this high-sulfur-content kraft process. The findings are available to the industry as a basis for mill design and industrial application to take advantage of the higher yields of pulp the process offers as compared with conventional kraft pulping.

In addition to findings given in the 1962 Annual Report, experiments in 1963 demonstrated that, for best results, the polysulfide liquor must be completely diffused and reactive with the wood before being brought to digestion temperature. This can be done either by using small or thin chips and extending the heating period to maximum cooking temperature, or by a two-step digestion, the first at 120° to 140° C. Either procedure is considered practical for kraft mills. Up to 20 percent more yield of bleached pulp was obtained with 12 percent of polysulfide sulfur on wood in the cooking liquor.

Chemical reaction studies revealed that yield was increased mainly by making the cellulose and glucomannan fraction of hemicellulose more resistant to alkaline degradation through the selective oxidation of reducing end groups of the molecule. The increase in xylan yield, however was small.

Studies of the possibilities of recovering useful chemical from the spent liquor of polysulfide pulping indicated that elemental sulfur might be recovered in worthwhile amounts. This can in turn be substituted for polysulfide in the kraft liquor up to an optimum sulfur level of about 7 percent and be nearly as effective as additional polysulfide. The 7 percent level appears to be close to the optimum, however, so the recovery of elemental sulfur for reuse has definite practical possibilities.

**Wood chips cooked in polysulfide liquor are dumped from experimental tumbling digester by Chemical Engineer James Laundrie.**




**Chemical reactions that take place during polysulfide experiments suggest desirable temperature schedules for commercial pulping.**

Under normal pulping conditions, polysulfide changes to sulfide and thiosulfate at digestion temperature. About 60 to 65 percent of the total sulfur is in the sulfide fraction of the spent liquor. Oxidation of the sulfide holds distinct promise as a means of recovering cooking chemical.

*Alkaline Sulfite Pulping.*—Experiments in the alkaline sulfite pulping of Douglas-fir, in which the liquor was fortified with sodium borohydride, produced large increases in yield of this pulp, which compares favorably with kraft in strength. Addition of 0.2 percent of borohydride, based on weight of the wood, increased yield 7 percent; additions of 0.5 and 1.0 percent brought yield gains of 18 and 22 percent, respectively. Alkalinity of the cooking liquor affected borohydride efficiency. Low alkalinity (pH 8 to 9) decomposed the borohydride, while at very high alkalinity (pH 13) the hemicelluloses were dissolved away.

The high cost of borohydride is expected to prohibit its commercial use for some time. Technological developments in alkaline sulfite pulping without borohydride, as detailed in the 1962 Annual Report, are nevertheless expected to bring it into use for pulping of softwoods.

*Post-Treated Bisulfite Pulps.*—Two-stage sulfite pulping with first an acid sulfite liquor—commonly called bisulfite pulping—and then a neutral liquor appears to offer sulfite mills an opportunity to produce more tear-resistant pulps that have all the other advantages of sulfite pulps, thereby putting them in a better position with respect to kraft mills. An alkaline post-delignification treatment of the cooked chips before they are fiberized, but after removal of most of the bisulfite liquor, was shown experimentally to increase tearing resistance substantially.

A relatively mild post-treatment with 2 to 3 percent of sodium hydroxide for 1 to 2 hours at 130° to 150° C. was used in these experiments. The yield of easily bleachable pulp was midway between those of bisulfite without post-delignification and kraft. Tearing resistance was close to that of kraft. The post-treatment can be accomplished without any major change in the equipment of existing sulfite mills.

The treatment has particular significance for sulfite mills confronted with installation of costly chemical recovery systems. Unless they can produce pulps more nearly equal to kraft in tear resistance, some industry leaders indicate doubt as to whether investment in recovery systems designed to eliminate pollution can be justified.

*Semichemical Pulping.*—Possibilities of a low-cost chemical recovery system for neutral sulfite semichemical mills now facing high capital investment in recovery plants are considered bright as a result of experiments with magnesia-base sulfite liquors.

While neutral magnesium sulfite is low in solubility, it becomes more soluble in liquors of moderate acidity. A treatment was worked out, therefore, that consists of impregnating mixed hardwood chips with bisulfite liquor followed by neutralization of the liquor to a pH of about 5.5 to 6 by injection of magnesium hydroxide. The resultant pulp was of acceptable strength and stiffness for corrugating medium, the principal product of neutral sulfite semichemical mills. Recovery of chemical is relatively simple and economical.

### Fiber Structure, Properties

An exploratory study is under way on the effects of swelling of fibers with chemical solvents and the resistance of fibers to swelling. One object is to facilitate the study of fiber structure; another is to investigate whether swelling has any effect on fiber bonding, which could have a bearing on paper sheet formation and strength. For this study, more than 50 kraft and prehydrolysis kraft pulps are being used which had previously been evaluated for chemical composition and strength.

A water prehydrolysis cook at 170° C. was found to have greatly reduced the resistance of sweetgum kraft fibers to swelling with a cellulose solvent. Prehydrolysis for 60 minutes lowered pentosan content to one-tenth that of the unhydrolyzed pulp, but the cellulose

molecules were shortened only about 6 percent. A 150-minute hydrolysis reduced pentosan content only one-half again as much as did the 60-minute hydrolysis, while the cellulose molecules were about one-third shorter than those of the 60-minute pulp. From this it was concluded that swelling resistance was lowered primarily because the cellulose molecules were shortened, since microscopic examination revealed that fibers given the longer prehydrolysis were swollen much more.

Even in sweetgum pulps given the longer prehydrolysis, the tertiary layer of the cell wall remained clearly evident under the microscope. This is in contrast to previous findings.

### Pulp Identification Method

A simple staining treatment was found to offer a means of differentiating clearly between cold soda and groundwood pulps under the microscope. When treated with Calcozine Red 6G Ex, cold soda pulps fluoresce a bright orange color and groundwood pulps yellow-green.

### Pulp Bleaching

A simple two-stage bleaching process that does not materially affect the high yield obtained with sodium bisulfite pulping gives promise of commercial value in the production of these pulps for papers bright enough to meet book and magazine standards. Bleaching processes commonly used to brighten sulfite pulps involve chlorination, which seriously cuts into the high yields obtainable with bisulfite pulping.

The new FPL process is based on calcium hypochlorite and sodium hydrosulfite. This treatment produced a satisfactory 76 percent brightness on a commercial spruce and hemlock sodium bisulfite pulp of 55 percent yield.

A three-stage process was developed that bleached kraft pulp to a brightness of 84 to 86 percent without using chlorine dioxide, an expensive bleaching agent. At least 95 percent of the strength of the pulp was retained. The process consists of a prehypochlorite stage, an oxidative extraction stage, and a mild oxidative stage. Calcium hypochlorite is used in all three stages with other chemicals. If used alone, it cuts pulp strength and gives the pulp an unstable brightness.

Conventional bleaching processes now used on kraft consist of five or six stages to attain the same brightness level. Since each stage represents a pollution problem, the simplified three-stage treatment has advantages here also.

### Papermaking Processes

A simple procedure for continuously adding a new starch size to pulp stock was used in studies in cooperation with the Northern Utilization Research and

**Washing bleached bisulfite pulp to remove excess chlorine and impurities, Technician Charles Coens pours it into Buechner funnel.**

Development Division of the U. S. Department of Agriculture at Peoria, Ill. The starch, a cationic dialdehyde, was developed at the Peoria laboratories as an outlet for surplus corn. Its electric charge attracts cellulose, hence it is readily added to cellulose fibers in paper without use of other agents commonly required. The starch gives a high degree of wet strength temporarily to paper, making it well suited for toweling and other similar products, yet is easily decomposed in alkali, thus facilitating its removal and reuse of the fiber. There is an estimated potential market of over 20 million pounds a year.

Further studies were conducted on techniques of utilizing expander rolls on the paper machine to stretch paper in width, thereby helping stiffen and

stabilize it dimensionally as described in the 1962 Annual Report. Different kinds of pulp were found to behave differently when thus stretched. Wet webs of chemical pulps could be stretched more than those of mechanical pulps, hence their properties were affected more. As the web became dryer on the machine with removal of moisture, however, chemical pulps developed more resistance to stretching than mechanical pulps. In another phase of this research, methods are being sought to prevent shrinkage of the web as it is dried after being stretched by the expander rolls.

#### Engineering Properties

New information on paper properties has been obtained that promises to be useful in the engineering design of paper products. For any given sheet thickness, stiffness has been shown to vary directly with tensile modulus of elasticity, and this modulus in turn with sheet density. If hand sheets are dried on disks as prescribed by the accepted TAPPI standard method, which restrains shrinkage equally in all directions, tensile modulus varies with the square of density. If shrinkage is not uniformly restrained, however, tensile modulus varies with the cube of density.

Considerable light has also been thrown on the manner in which sheet properties can be changed during manufacture. Industry opinion is generally that the ratio of sheet properties in the machine direction to those in the cross-machine direction is dependent only on the formation of the sheet on the paper machine drainage wire. Recent FPL findings, however, show that, while the tearing strength ratio is highly dependent on fiber orientation in the sheet, other properties, notably tensile strength, tensile modulus of elasticity, and dimensional stability, are highly dependent on the manner in which the wet sheet is stretched and restrained from shrinking as it passes through the drying sections of the paper machine.

**This three-dimensional graph is used by Technologist Vance Setterholm to demonstrate how fiber orientation and degree of restraint during drying affect stiffness of paper as measured by modulus of elasticity.**

**As plant construction moved ahead during 1963, southern pine plywood industry technical committee met with FPL staff to discuss quality standards and related research. Around FPL conference table are, from left, Edward W. Kuenzi, in charge of FPL engineering design criteria research; Lyman W. Wood, in charge of buildings and structures research; Harold L. Mitchell, Chief, Division of Wood Quality Research; Thomas M. Orth, Vice President, Kirby Lumber Co., Houston, Texas; N. Thomas Shelton, Engi-neer, Potlatch Forests, Inc., Lewiston, Idaho; Edward G. King, Technologist, and John Hess, Research Director, Douglas Fir Plywood Association, Tacoma, Washington; Harold A. Bonnet, Office of Commodity Standards, U.S. Department of Commerce, Washington, D.C.; Dr. Robert W. Hess, Director of Research, Georgia–Pacific Corp., Portland, Oregon; Dr. H. O. Fleischer, Chief, Division of Solid Wood Products Research; Joseph A. Liska, Chief, Division of Wood Engineering Research; D. L. Fassnacht, Southern Forest Experiment Station, New Orleans, Louisiana; and Robert L. Youngs, in charge of fundamental properties research.**

# SOLID WOOD PRODUCTS RESEARCH

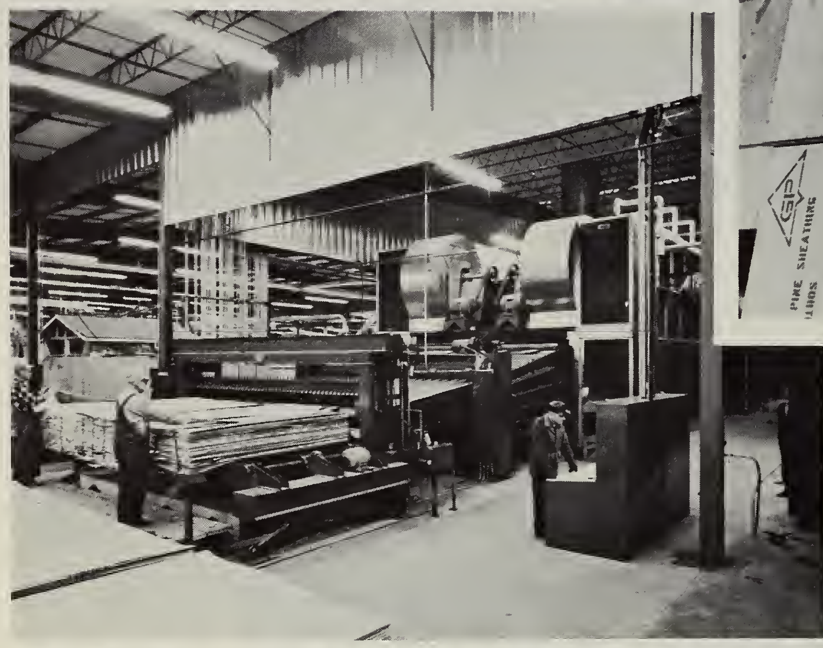
The many processes involved in bringing wood from the log to the finished product—machining, seasoning, gluing, preservative or other chemical treatment, and painting or other finishing—are all included in the category of FPL work called solid wood products research.

Processing involves both primary products—veneer, plywood, laminated wood, even particle board—and secondary ones such as building components and furniture. Generally, however, FPL research in this area of solid wood products is concerned with basic problems, solutions to which have broad application. Examples are the effectiveness of preservatives against various types of decay, fungi, and insects; new methods of cutting, seasoning, and machining wood; the kinds of degradation that occur when wood is heated; and the effects of sunlight and other weathering agents on wood that is painted or naturally finished.

## Plywood and Veneer

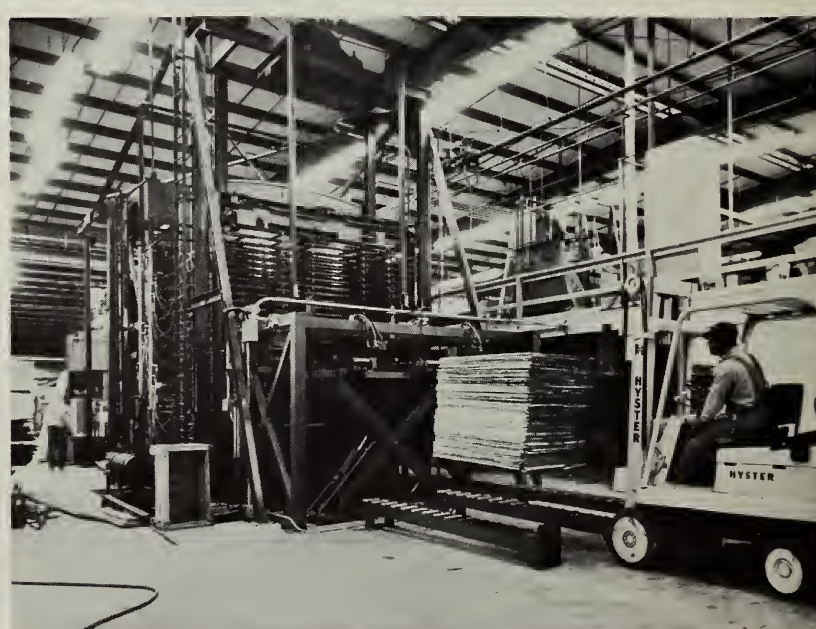
Seldom if ever have results of FPL research moved as quickly or extensively into industrial use as did the work demonstrating the feasibility of southern pine plywood, as detailed in the 1962 Annual Report. During 1963, public announcement was made by four companies that at least three such mills would be built, and construction was begun on two.

Meanwhile, industry agreement was reached on a new commercial standard for southern pine plywood in the drafting of which FPL technologists played a leading part. Significantly, it was the first time in the history of such standards promulgated by the Commodity Standards Division of the U. S. Department of Commerce that one had been adopted before the product covered was in actual production. And the

**First southern pine plywood plant went into production in 1963 at Fordyce, Arkansas. Upper left, logs await cutting into veneer; upper right, southern pine sheathing on house wall; center, feeding veneer into giant dryer; lower left, laying up freshly glued veneers; lower right, multi-opening hot press for curing glue in plywood assembly.**

(Photos courtesy Georgia Pacific Corp.)



Douglas Fir Plywood Association not only agreed to provide inspection and quality control services, but contemplated changing its name to reflect its new and broader national functions.

Inquiries continue to come in from landowners, public officials, and other interested in producing southern pine plywood throughout the South. FPL technical information about requirements as to raw material, plant, equipment, and other physical needs and the technological problems involved in production is of significant value to such people.

In general, raw material requirements for plywood have been carefully developed to assure that a quality product will reach the market. One of the biggest concerns of the new industry's leaders is that the product become established as suitable in every respect for use as structural sheathing, the primary use for which it will be made in the immediate future. Certain technological features, such as density and rate of growth of the raw material and proper veneer cutting, drying, and gluing procedures, must be considered in establishing the new product in the sheathing market.

Gluing studies of southern pine veneer showed that phenol-resin exterior glues and extended interior-type phenols were generally adequate. Hot-press protein-blend glues were somewhat marginal for interior-type plywood. Extensive pitch, when present, tended to give veneers a glazed appearance and interfere with gluing.

Meantime, research on Slicewood, a type of veneer approaching lumber in thickness, moved toward a new, more comprehensive approach as work proceeded on the design of an experimental slicing machine. Previous experiments had been done on a modified conventional veneer slicer. The new machine will be much more versatile for experimental purposes. The new machine will also be able to cut Slicewood up to 1 inch thick—twice the thickness capacity of the old equipment.

#### Wood Drying

In cooperation with the Alexandria, La., Research Center of the Southern Forest Experiment Station, experiments were conducted to compare three ways of drying Slicewood. These were a conventional veneer dryer, hot-press drying, and a commercially developed jet, or air impingement, method. Drying times were 90 minutes in the conventional dryer, 56 in the jet dryer, and 23 in the hot press. The dried material is being evaluated to compare results of the three methods.

FPL drying specialists worked closely with the American Lumber Standards Committee in an advisory capacity with regard to new lumber sizes under revised standards. In particular, a question arose concerning the amount of shrinkage which lumber surfaced while green would undergo while drying. Analysis of previously worked out shrinkage statistics showed that, assuming an average 30° angle of the annual rings to the wide surface of the lumber, the piece would shrink on the average 2.8 percent in width and 2.35 percent in thickness. These calculations were verified within a few hundredths of 1 percent by an independent study at the Oregon State University Forest Research Laboratory.

A basic study of the stresses that develop in ponderosa pine as it dries was conducted on 2-inch-thick planks. Strains indicating such stresses were measured at various depths throughout the thickness by cutting the specimens into 10 slices. Strains that developed were more complex than those occurring in oak heartwood previously studied, being affected by radial differences in the drying characteristics of sapwood and heartwood as well as by irregular distribution of moisture. Appropriate final conditioning, however, relieved the strain-inducing stresses.

A companion study of the perpendicular-to-grain mechanical properties of ponderosa pine at various temperatures and moisture content levels during drying is reported under Wood Engineering Research.

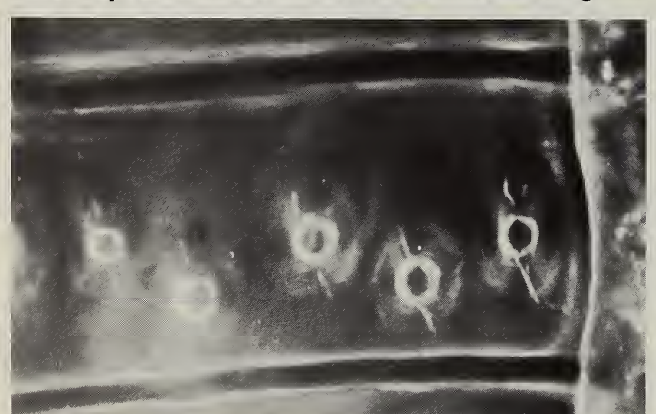
#### Glued Products

Research is under way on the chemical reactions between glues and fire retardants that are believed responsible for difficulties encountered in the gluing of wood treated with retardants. Preliminary results indicate that the trouble may stem from interactions between ammonium ions and formaldehyde in the glue. Earlier research had indicated something of the sort; premature gelation of the glue occurred during the curing process, apparently because of chemical interference by the fire-retardant salts. Research is continuing in an effort to pin-point the chemical mechanism that causes gelation. Once that mechanism is understood, methods of preventing or minimizing it may become apparent. High fire resistance is often desired in plywood, laminated wood, and other glued products, and a breakthrough here would stimulate use of wood in certain types of construction where it is not now used.

Finger joints are used to join pieces together end to end. This type of glue joint is economical of material as compared with the scarf joint but falls short in strength. Experiments with finger joints of various designs showed that the slope of the fingers—that is, the angle of cut used to make them—is a critical factor in joints of this type, another being the width of the finger ends. The narrower the finger ends and the flatter the finger slope, the more fingers can be made in pieces of given widths, increasing the surface area bonded together with glue. The study provided a needed mathematical approach to the finger-joint design. Finger slopes ranging from 1:10 to 1:16 did not cause great variations in strength of joints, the experiments disclosed.

**Radiation effects on wood underneath natural finish are photographed by Technologist Victor Miniutti.**

**Breaks in cell wall around bordered pits are clearly seen in microscope under natural finish on wood specimen after accelerated weathering.**



### Wood Finishing Research

Success in developing longer-lasting paints and other wood finishes for outdoor use will hinge largely upon improving the protection they give from the ultraviolet portion of sunlight. This conclusion has been drawn from FPL experiments designed to measure the effects of ultraviolet rays on wood.

When varnished wood was exposed to ultraviolet rays, the surface fibers directly underneath the finish deteriorated seriously, microscopic examination revealed. Checks and splits developed around the bordered pits (microscopic openings) in the walls of springwood fibers and spirally in walls of summerwood fibers. Separation of fibers from one another was also observed. Walls of some cells were seriously damaged.

While these injurious effects were sustained under severe laboratory conditions not directly related to normal outdoor weathering, they are considered indicative of what sunlight can do over a period of time. The resulting strains, although microscopic in size, are considered capable of imposing stresses severe enough to cause premature coating failure.

In another series of experiments, data were obtained on the photochemical actions induced by ultraviolet light when it strikes wood. Finely ground wood flour was exposed, in the presence of air, to the ultraviolet rays in a sealed glass tube. Gases given off during the exposure period were captured and analyzed, and significant amounts of carbon dioxide, carbon monoxide, and methanol were found to be produced by the irradiation. Analysis of the wood after exposure to this radiation showed that its methoxyl content was significantly lowered and its acidity markedly increased.

When the irradiation was conducted in an atmosphere of nitrogen gas, photochemical and oxidation reactions were greatly reduced and the irradiated wood was considerably less acid. Microscopic examination of the wood indicated that the most serious damage was sustained by the walls of ray cells.

Evaluation of various finishing systems under long-time outdoor exposure continues to yield useful information on painting systems. Of particular interest is the continued good performance of three-coat painting systems, now 8 years old, on southern pine boards overlaid with resin-treated paper. Only the porous breather-type oil-base paints show rapid erosion.

Also noteworthy is the long life—now 8 years—of FPL natural finish on rough-sawn cedar. This stain, developed some years ago to meet a need for more durable natural finishes on exterior siding and other wood surfaces, has a much longer service life on rough-sawn than on smooth surfaces.

### Fire Resistance of Wood

Wood chemically treated with fire retardants chars more and gives off less flammable tar than untreated

wood when heated, according to results of FPL experiments designed to provide basic information on how these chemicals protect wood from fire. Wood containing 6 percent by weight of diammonium phosphate, for example, produced from 20 to 45 percent more protective char and from 17 to 55 percent less flammable tar than untreated wood when heated for 2 hours at 350° C.

The experiments were performed in an inert atmosphere of helium gas, so that all byproducts of heat could be recovered and analyzed. This type of heating in the absence of oxygen to avoid actual burning is called pyrolysis. Wood treated with 33 fire-retardant chemicals was used in these experiments. The effectiveness of each chemical was evaluated on the basis of the lowest temperature at which pyrolytic decomposition of the wood began and the amounts of volatile gases produced at different temperatures.

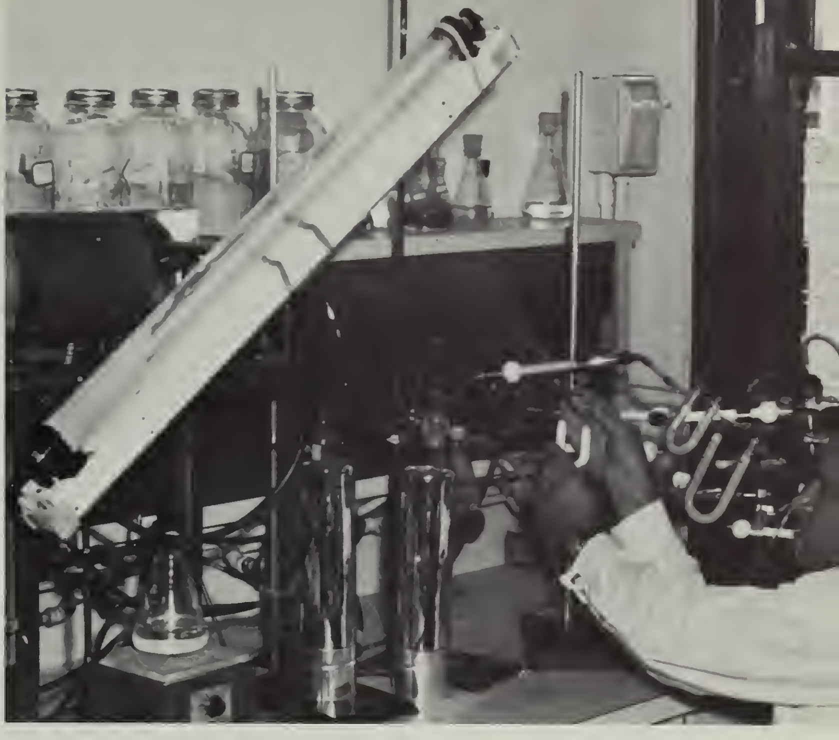
In addition to wood, the experiments were conducted on alpha cellulose and lignin in order to compare the decomposition characteristics of these two major chemical components of wood. The cellulose began to decompose chemically at a lower temperature when treated with fire retardants than when untreated.

Similar experiments were run in an oxygen atmosphere to study flaming and glowing characteristics. Results indicate that the cellulose in wood flames at a lower temperature and longer than lignin does, but that lignin tends to glow more and longer than cellulose. Fire retardants reduced the amount of heat contributed by these flaming and glowing reactions at the lower levels of the temperature range used.

It has long been known that heavy wood beams and other structural members have exceptional resistance to fire because the char formed actually insulates wood from the heat and thereby slows down or actually stops burning before the timber is critically weakened. The rate of char formation has generally been assumed to be about 1½ inches an hour under fire conditions.

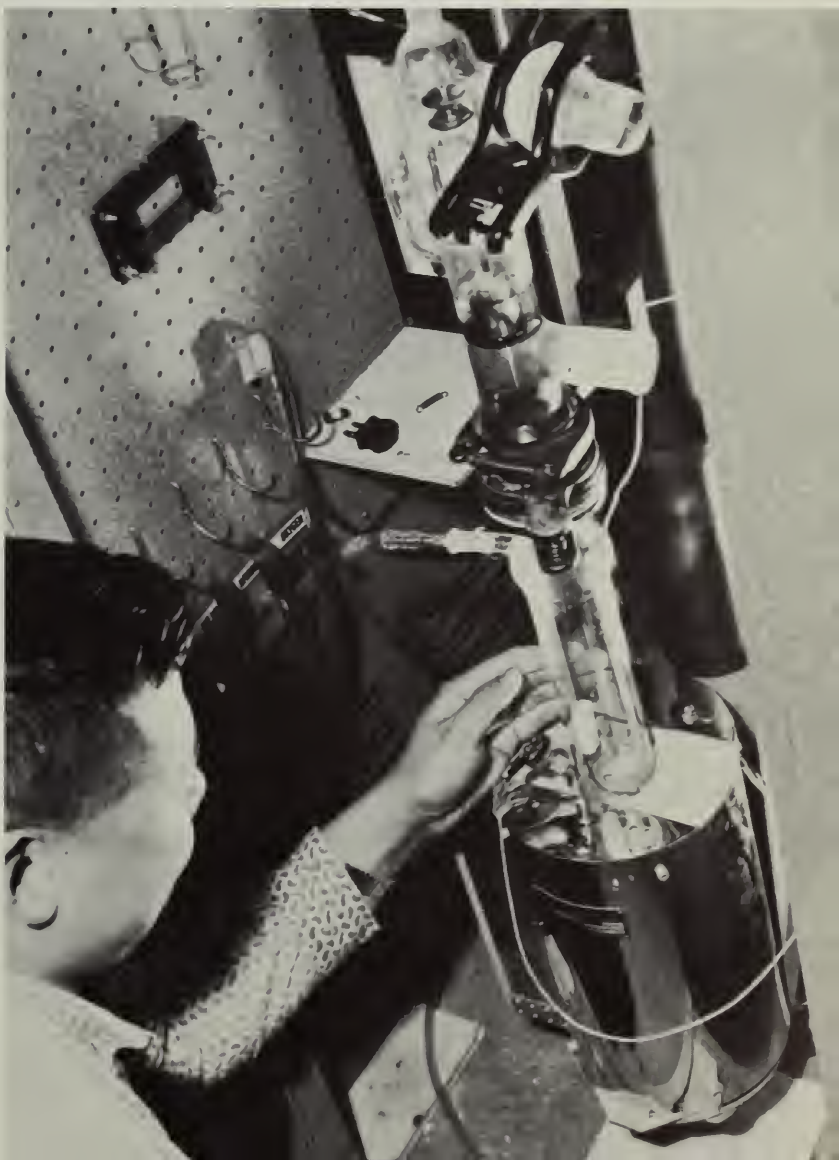
Experiments are now under way in cooperation with the National Lumber Manufacturers Association to get more precise information on rate of char penetration and the effects on charring of species, wood density, grain direction, moisture content of the wood, and heating temperature. Douglas-fir, southern pine, and white oak specimens 3 inches thick, 10 inches deep, and 20 inches long are exposed to fire in a gas-burning furnace, and temperatures along the depth and length of the piece are recorded.

Data obtained on Douglas-fir so far indicate that the char line temperature under the rapid heating condition used is about 550° F. and that the accepted rate of penetration, 1½ inches, is quite applicable to this species. Other tentative conclusions are that the denser Douglas-fir specimens char more slowly, and that those containing more moisture also char less rapidly up to



**Chemist Martin A. Kalnins adjusts trap designed to catch chemicals given off by finely ground wood when exposed to ultraviolet radiation in oscillating tube at left.**

**Glass tube in which wood shaving is suspended in nitrogen gas is lowered into electric furnace for pyrolysis experiment by Chemist Walter Tang.**



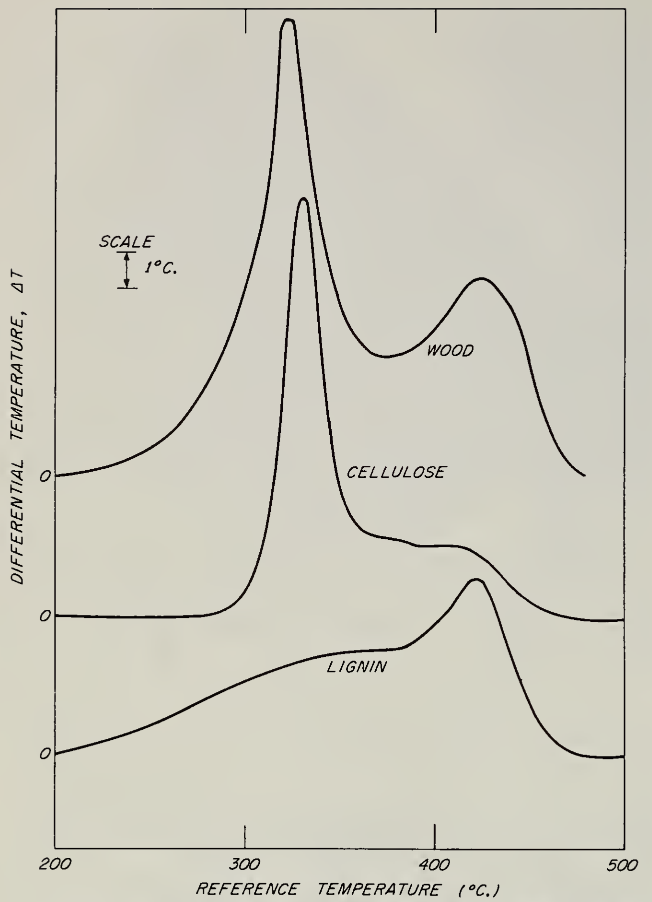



**Chart of differential temperatures (heat generated by wood, cellulose, lignin heated to same temperature as inert substance) shows that cellulose flames to peak temperature sooner than lignin.**

about the 14 to 16 percent moisture content level; above this level the char scales off from edge-grained surfaces, thus increasing the penetration rate.

Fire exposure and strength studies are also planned under this cooperative project with the object of developing design criteria for more fire-resistant wood structures.

### Environmental Research

The launching of research aimed at establishing the effects on wood of widely dissimilar climatic conditions in four regions of the United States and determining actual conditions at the microclimate level was described in the 1961 and 1962 Annual Reports. Exposure sites are now well set up with various types of wood materials near Olympia, Wash., Fresno, Calif., and Saucier, Miss., as well as Madison, Wis.

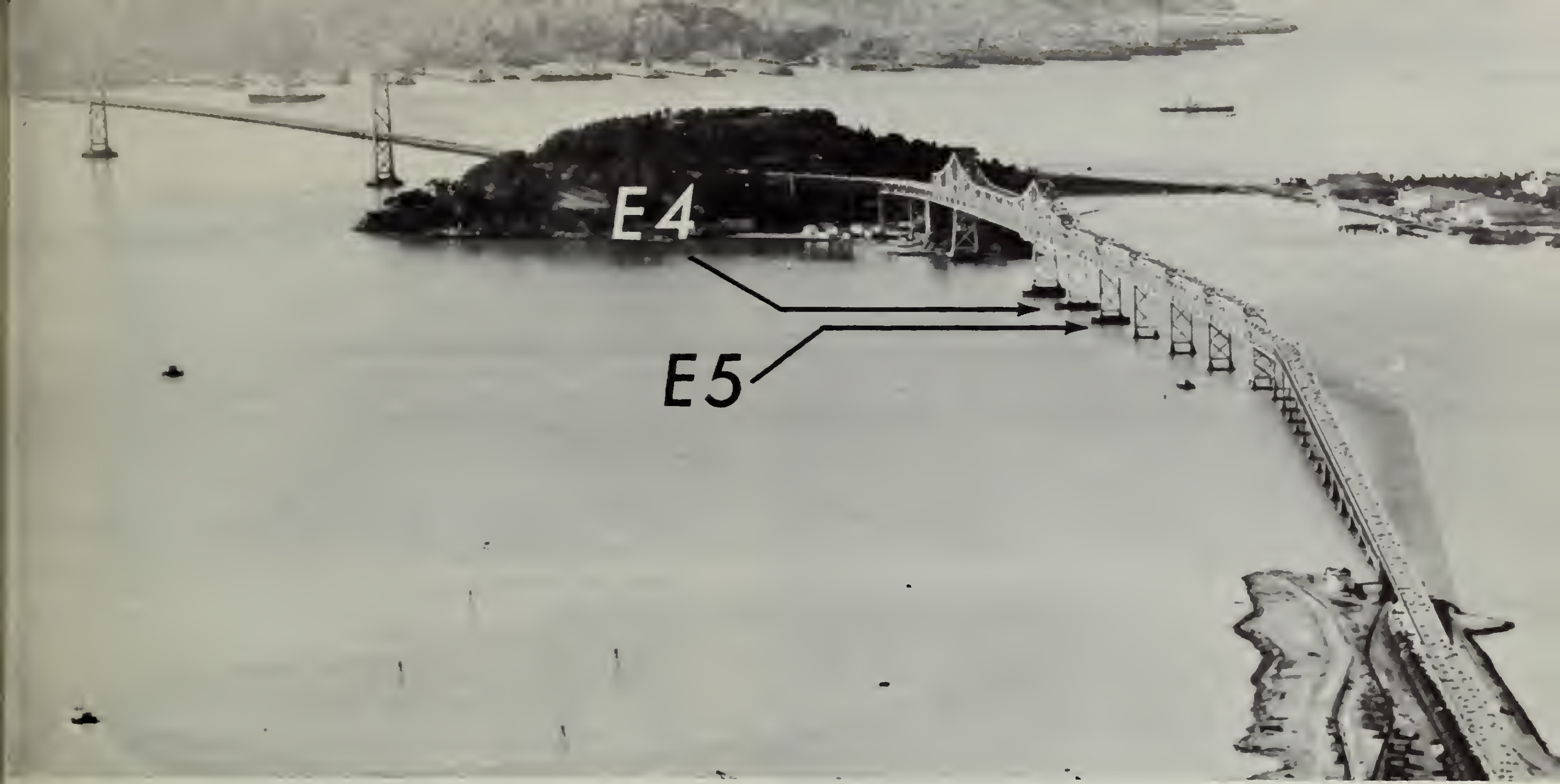
Because the program is new, it has been necessary to develop new techniques and instrumentation. Two instruments developed and put to use at Madison on a trial basis during 1963 were a solar energy totalizer used to record the amount of energy striking a surface during a period of time, and a moisture content probe that is noncorrosive and can be permanently mounted in a specimen for measuring moisture content gradients from surface to interior. Under development are an automatic card punch system that will facilitate processing of the great amounts of data obtained and an electronic device that accumulates temperature-hours at different levels of temperature.

Studies of microclimate—temperature and related conditions on the surfaces of materials under observation—were begun with measurements of electromagnetic radiation, both longwave (infrared) and shortwave (ultraviolet), on surfaces of wood products in exterior exposures. Among significant findings were unexpectedly rapid and wide fluctuations in surface temperature. A black-painted board, for example, dropped 30° to 40° F. and recovered its original temperature within 10 minutes when the sun was temporarily obscured by a cloud. It seems reasonable to expect that such drastic temperature changes can induce rapid thermal stresses and moisture content changes that in turn can seriously affect the durability of finishes and adhesives.

Longwave radiation was found to have an unexpectedly pronounced cooling effect when two boards, one painted black and the other white, were exposed to afternoon sunshine side by side. The black-painted board became much warmer than the other, even though the air temperature was only 10° F. As the sun dropped lower, the white board cooled until it was actually 6° F. below the air temperature, while the black one, although also cooling, remained much warmer than the air. This unexpected development was ascribed to the slightly greater longwave emissivity of white paint. Similar effects have been noted since, during both winter and summer. One result is the earlier formation of dew on the white-painted than on the dark-painted surfaces.

### Decay Protection for Buildings

Preservatives and treating methods suitable for houses and other structures—especially parts vulnerable to decay infection, such as porch steps and railings and window and door trim—are under development in cooperation with the Bureau of Yards and Docks, Department of the Navy. Before paint was applied, vulnerable points, especially joints where water can collect, were heavily sprayed with preservative oils such as pentachlorophenol dissolved in light petroleum oil, or coated with grease-type preservative. Laboratory assays of effectiveness show considerable promise, although definite shortcomings have become apparent that indicate need for further experimentation.




**Assays of creosote in cores taken from fender piling of San Francisco—Oakland Bay Bridge at Piers E-4 and E-5 showed both quality and quantity still good in 1963 after 29 years.**

The flooding treatment was ineffective on older, previously painted structures, and this phase of the investigation was discontinued.

A decade ago, wood given a 3-minute dip in a 5 percent solution of pentachlorophenol in light oil was assembled into simple jointed structures resembling porch railings and exposed outdoors. Inspection last year showed they are still withstanding decay attacks well. Specimens were set out at Corvallis, Oreg., and on the Harrison Experimental Forest near Saucier, Miss., as well as at Madison.

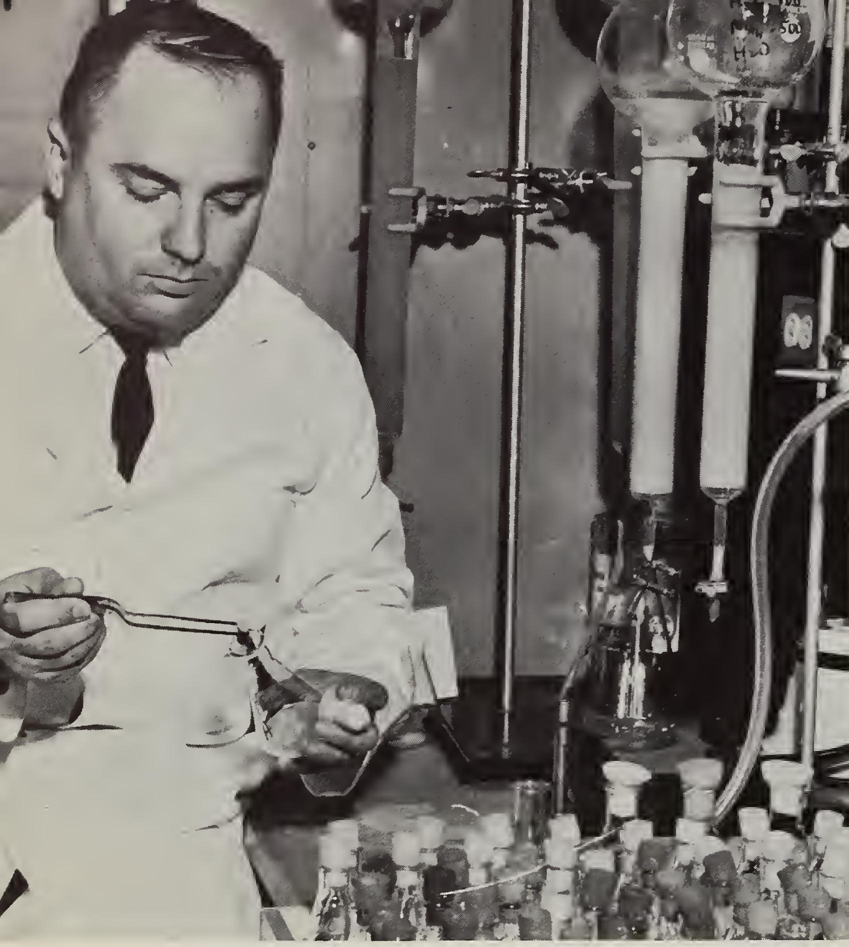
### Control of Wood-Attacking Insects

Promising results were obtained from preliminary field appraisals of the effectiveness of a termite attractant, discovered several years ago, in controlling infestations of these wood-destroying insects. Encouraging evidence was also obtained that termites may be controlled by combining the attractant with fiberboard that has been treated with a commercial insecticide, Dieldrin. Experiments are being continued to determine whether the insects carry the insecticide to their nests—a step believed necessary for successful control.

A longtime study of termites with relation to their surroundings and life cycles has brought out the fact that they survive better under given surroundings when nurtured on decay-infected wood. The kind of fungus present, however, appears to be more influential in terms of termite survival than the amount of decay. Investigation of the significance of this finding is continuing.

### Bacterial Infection

Research on the effects of bacterial infection of wood led to the discovery that the membranes covering cell-wall pits (minute openings in the walls of wood cells) are destroyed by certain bacteria. If further study confirms this finding as a typical result of such infection in wood, it will for the first time adequately explain why such wood is much more porous to liquids than uninfected wood. The finding may hence prove useful to technologists in the development of better chemical treatments for protection of wood from fungi and insects.




**Physiologist Karl Wolter inserts a stem with living cambium into a flask containing nutrients for cell propagation.**

# WOOD QUALITY RESEARCH

The many-sided nature of wood quality is plainly seen in the numerous avenues taken by research in this field. Some characteristics of wood are prized for certain uses but avoided or stringently limited in material selected for others. Knots, for example, enhance beauty but may impair strength. The manner in which the raw wood is prepared and processed likewise bears importantly on its suitability, and therefore its quality, for specific uses. Quality criteria, in fact, range from the precise mathematics of engineering formulas to the sometimes whimsical preferences of consumers.

Research on wood quality at FPL is chiefly concerned with the determinants of quality in the raw material—that is, with wood structure and growth and the processes and conditions influencing them. Such long-accepted quality criteria as density, rate of growth, and fiber slope are controlled by inherited species characteristics and growing conditions. Research is done to define and gain understanding of the relationship between quality criteria and factors controlling them, with the object of ultimately producing wood better suited to our needs.

**Physiology of Wood Formation**

During 1963 a new basic line of wood quality research was begun on the growth of wood tissue under laboratory conditions—literally, *in vitro* or "in glass." The object is to study how wood tissues—phloem, xylem, ray cells—are formed from the cambium, and how their formation and development can be controlled.

Under normal tree growth, various types of xylem (wood) and phloem (bark) cells are formed each year from the cambium. Water moves upward from the roots through the xylem, bringing minerals from the soil. By photosynthesis and other processes, the leaves manufacture cell nutrients that move downward through the phloem.

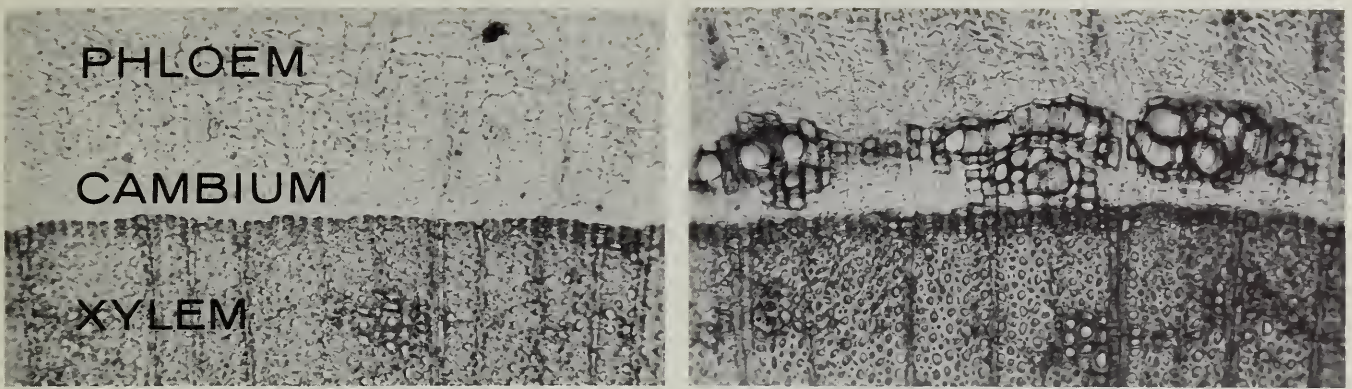
A basic aspect of this research is to learn how a particular nutrient affects cell growth. To study such effects, wood cells are grown in flasks under controlled conditions. One by one and in various combinations, the nutrients needed for growth are varied in amount —literally from a starvation level to excess. Such precision is, of course, impossible under normal conditions of cell formation and growth in the tree, where weather, climate, soil conditions, and other factors control the efficiency of roots and leaves.

This research is now mainly in the first of three stages of a longtime program of physiological and biochemical research. This stage is designed to establish laboratory conditions for cambial tissue culture, such as sterilization procedures necessary to remove unwanted micro-organisms, suitable techniques for reproducing cambial tissue, and methods of using small stem segments from living trees to reproduce cells.

The second stage involves development of synthetic nutrients and growth conditions by determining nutritional requirements, growth hormones needed, and the physical conditions necessary, such as temperature, light, and humidity. A few preliminary explorations indicate that certain nutrients are highly significant in formation of ash xylem.

When the first two stages have been adequately explored, ways of controlling growth and division of cells will be sought. A key goal of this third stage will be the control, by dietary means, of summerwood and springwood formation in the annual ring, because the thicker-walled, denser summerwood cells provide stronger wood. The causes and control of cell growth in a spiral direction around the tree will also be sought, because spiral growth is known to weaken wood. Control of phloem and ray cell development is another target.

The better understanding of wood cell formation and development thus obtained is expected to prove highly useful to foresters in guiding them toward more effective means of growing trees for wood quality.




**Growth of normal cambial tissue (left) as compared with that of cells stimulated by hormones and nutrients.**

### Quality of Standing Timber

At the opposite end of the quality research spectrum from the new cell formation study is the quality survey of standing timber under way for some years in the South, West, and Maine. This survey, based on increment-core samples taken from living trees for laboratory analysis of density, age, growth rate, sapwood thickness, and other quality criteria, has been reported in detail in the 1961 and 1962 Annual Reports.

During the past 3 years, the survey of 11 western States has been strongly pushed, with a target date of June 30, 1964 for a final report to the cooperators. For this work the Western Pine Association, West Coast Lumbermen's Association, and Douglas Fir Plywood Association have contributed $300,000 to help finance gathering of cores by crews of the Pacific Northwest, Pacific Southwest, Intermountain, and Rocky Mountain Forest Experiment Stations, as well as to support laboratory analysis at FPL.

With a few minor exceptions, all collecting of wood samples, specific gravity determinations, and computations of statistical data have been completed for the western survey. Analysis of the data and report preparation were well under way at year's end. Of some 30 species involved, nine have been concentrated on because of their commercial importance. These are Douglas-fir, western hemlock, western larch, white, grand, Pacific silver, noble, and California red fir, and black cottonwood. In addition to increment core sampling, trees of these species have been cut down and sampled at various heights to get a statistical basis for estimating wood density of the entire merchantable tree trunk. Engelmann spruce and western redcedar are being similarly sampled.

Sampling of southern pine in seven States is in various stages of progress. The data on Mississippi, the State where the whole program began as an experiment, have been published. Data for Georgia, Florida, Alabama, and Arkansas are being statistically analyzed. In North Carolina and Louisiana, core samples are being gathered. In addition, whole trees are being sampled in Arkansas, Georgia, North and South Carolina, and Virginia to determine how the density of increment cores taken at breast height reflects overall density of the wood in the merchantable bole of the tree.

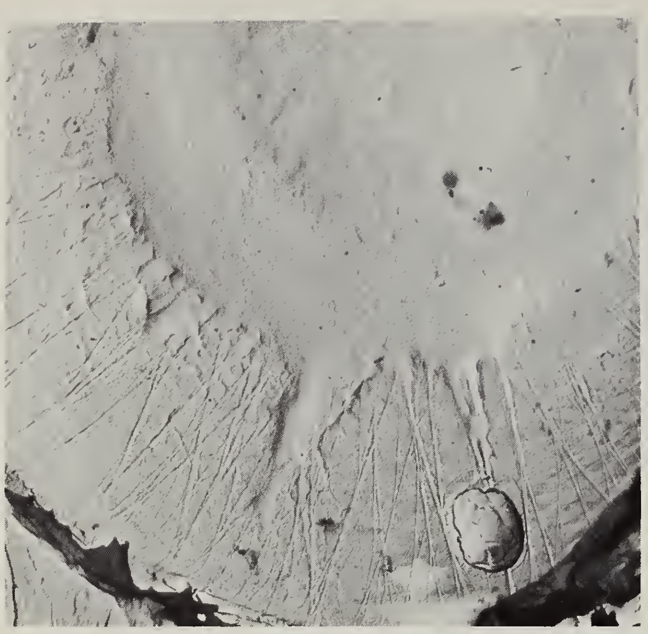
For the South as a whole, it is expected that within 5 years a reasonably complete quality picture of southern pine standing timber will be available. Already, however, information has been put to effective use by timber owners and managers, State forestry officials, and wood products manufacturers.

Wood processors who have found survey information already of value include utility pole and piling producers, laminators, and pulp manufacturers. In the South, poles of high density are desired, and areas where such wood grows are clearly indicated in the survey findings. In the West, pole producers want trees with thick sapwood bands, since heartwood of Douglas-fir and some other common pole species is difficult to treat with preservatives. Laminators need material meeting exacting specifications for strength and stiffness, and survey findings help them locate likely sources of it. Most pulp manufacturers want dense wood because it yields more fiber.

Research is continuing on the chemical composition, microscopic structural variations, and machining characteristics of the wood in the core samples.

### Fine Wood Structure

Photographic evidence that lignin softens and flows when wood is heated was obtained by an FPL staff member doing advanced research in electron micro-



**Evidence that lignin melts when wood is heated was obtained in this electron micrograph showing lignin of torus flowing down bordered pit membrane.**

**Southern pine log being flitched in experiment designed to develop more efficient sawing methods for production of studding.**

scopy while in Europe under authority of Public Law 85–507. His research was done at the Institute for Forestry Research, University of Munich, Germany.

It has long been assumed that, when wood is heated or compressed, the lignin is plasticized, and that this accounts for the fact that, after the compressive force is released, wood remains in a compressed state. Recent studies at FPL have demonstrated that lignin is present in quantity throughout the complex wall structure of wood cells, which consists of several layers.

Electron microscope studies have shown that the inner surface of the cell wall has a wartlike appearance. These warts are thought to consist of a large quantity of lignin, as are the lignin-containing toruses that screen the pit openings in cell walls.

Electron microscope examination of wood samples that had been heated to 190°, 200°, 220°, and 240° C. in a thermogravimetric balance without air for 2½ hours clearly showed that both the warts and the toruses liquefy and flow. At these temperatures, the cellulose appeared to be unchanged.

Although these findings are preliminary in nature, they lead to interesting speculation about their significance. Since lignin softens before heat affects cellulose, it appears to have a protective as well as an adhesive role in wood. It is possible, therefore, that further research may lead to more effective fire retardants chemically designed to inhibit the softening of lignin and thus modify pyrolysis and combustion processes. Until research can be greatly extended along these lines, however, such possibilities must remain purely speculative.

### Sawmill Improvement

Although their numbers have been decreasing in recent years, sawmills still utilize the largest proportion of the round wood from the forest. The quality of their output varies greatly. For many years FPL has done research aimed at improving sawmill efficiency and products.

During 1963, an intensive study was underway to compare the effect of sawing method on the quality of 2 by 4 studs. The main object of the work was to increase the yield of studs relatively free of crook, or edgewise warp, which disrupts the flatness of wall surfaces in a structure and therefore is strictly limited by grading rules. Crook occurs commonly in studs cut from small logs, which contain relatively large percentages of "juvenile" wood surrounding the pith. Studs that contain both juvenile and normal wood are especially likely to warp, because juvenile wood shrinks much more lengthwise when drying than does normal wood and consequently pulls the studs out of shape.

A method of sawing was devised to remove the log taper and much of the slab from the juvenile area, thus reducing or eliminating the occurrence of juvenile

wood in the studs. For this work a supply of loblolly pine logs was obtained from the Hitchiti Experimental Forest in Georgia with the cooperation of the Southeastern Forest Experiment Station and the Georgia Forest Research Council.

Preliminary findings indicated that the FPL method is especially effective in increasing the yield of crook-free studs from butt logs, which generally contain more taper than logs higher in the tree and in which the pith is often off center. These butt logs yielded an average of 27 percent more studs meeting the straightness requirement of the No. 1 Dimension grade than were obtained by the conventional method of sawing with a single circular or band head saw. Logs were selected from four diameter classes, 6, 8, 10, and 12 inches. Logs with a top diameter of 10 inches yielded up to 35 percent more crook-free studs.

Logs from higher in the trees yielded much lower percentages of studs prone to crook, and consequently the FPL method, though still superior, proved less advantageous. The reasons for this are not clear, and studies are continuing. The FPL sawing method may be tried on another southern pine species and a western softwood to compare results obtained with the loblolly pine and to provide additional information about different results obtained with butt and upper logs.

Another type of abnormal wood, called compression wood, was also taken into consideration in devising sawing patterns. This abnormal wood also shrinks much more than normal wood lengthwise, hence has the same tendency to warp studs containing both normal and compression wood. Since compression wood occurs much more randomly in logs than does juvenile wood, sawing patterns must be designed to confine it to as few studs as possible. Where both normal and compression wood are unavoidable in a single stud, sawing patterns that induce bow, or flatwise bending, rather than crook are being tried out. Bow does not distort wall flatness as does crook.

Basic research on sawtooth design has produced some encouraging results in the way of better adapting the FPL Duo-Kerf saw principle to sawing of logs. The inherent advantage of the principle is the smoother cut produced, for many uses making planing unnecessary.

The Duo-Kerf saw has alternating chipper and planer (side-dresser) teeth. In experimental sawing of hardwood logs with "wild" grain, it was found that the Duo-Kerf saw cut less accurately than a conventional saw. This was ascribed to the fact that the chipper teeth had to bite more deeply into the wood than teeth on a conventional saw at a given feed and saw rotation speed, because there were only one-half as many. The chipper tooth was therefore redesigned to combine in a single "step-tooth" the effect of a pair of teeth. Preliminary sawing trials have yielded encouraging results, and experiments are continuing with step-tooth designs.

A study of grade yields and lumber values of No. 1 and No. 2 factory grade yellow birch sawlogs provided results of economic interest to sawmill operators. When Select and No. 1 veneer logs were withdrawn, the effect on the value of the remaining sawlogs was analyzed. For example, 17 percent of a typical group of 16-inch No. 1 sawlogs valued at $196 per thousand board feet were found to qualify as Select veneer grade logs. The veneer logs were worth $240 per thousand board feet as lumber. When they were taken out, however, the lumber value of the remaining sawlogs dropped to $186 per thousand board feet.

Likewise, 53 percent of the logs qualified as No. 1 veneer logs worth, as lumber, $210 per thousand board feet. The remaining logs, however, dropped in value to $177 per thousand board feet. Such findings, when compared with market value of veneer logs, indicate how loggers and sawmill operators can determine whether it pays to segregate logs for different uses.

### Wood Identification Service

During 1963, requests for the Laboratory's free wood identification service increased to 861 from 815 the previous year. The number of specimens received for identification climbed much more sharply, from 2,658 in 1962 to 4,884—an 84 percent gain. Both requests and specimen numbers set new all-time highs.

**Gelatinous fibers in oak are studied in a viewscope by Microscopist John Quirk.**

These records may not last long, however. A new federal law requiring manufacturers to label their products as to species of wood, whether solid wood or plywood is used, and whether one kind of wood is finished to resemble another species, is expected to increase public demand for the identification service.

As usual, a wide variety of wood samples were sent in for identification. Among the more noteworthy were artifacts and charcoals from ancient civilizations of Crete, Turkey, Iran, Greece, Ceylon, and Guatemala. Police investigating the kidnapping and murder of two Minnesota children asked for identification of woody materials found on the clothing of the bodies in an effort to determine where the killings occurred.

The FPL's collection of domestic and foreign wood samples grew by 272 as a result of exchanges with other agencies. It now numbers 22,080, one of the largest and best authenticated in the world.

**The annual rings of this disk cut from a 784-year old redwood log 38 inches in diameter form an attractive pattern in a coffee-table top. Disk was stabilized with polyethylene glycol against splitting and checking as it dried—long a barrier to such uses.**

# WOOD CHEMISTRY RESEARCH

FPL's research in wood chemistry has as its goal a better understanding of basic chemical reactions essential for industrial processing, more complete knowledge of the chemical structure of wood and its chief chemical components, and modification of the properties of wood by chemical or physicochemical means. Research is oriented toward the job of creating and maintaining markets for wood as a raw material for industrial chemicals. Uses are sought especially for wood not utilizable for solid wood and fiber products—that is, low-quality standing timber and logging and milling residues.

### Lignin Pioneering Research

The fundamental nature of much FPL research was sharply accented during 1963 with the establishment of a pioneering research unit in lignin. Heading up the unit is John C. Pew, whose research at FPL for many years had been devoted to the problem of characterizing lignin chemically to create a foundation on which applied research can build.

Under the new setup, Pew has virtually complete freedom to explore the fundamental aspects of lignin chemistry. Administrative and reporting requirements ordinarily attached to research project leadership are held to a minimum.

Pew has contributed much to knowledge of the molecular structure of lignin—a component much more complex than cellulose or hemi-cellulose, the other major chemical constituents of wood. Its complete characterization still eludes chemists.

Among Pew's contributions have been the elucidation of the actual chemical structure of compounds formed in the phloroglucinol and aniline color reactions of lignin; finding how to isolate the whole of the lignin in wood without substantial degradation by dissolving away the carbohydrates in finely ground wood by the action of cellulytic enzymes; and demonstrating, by various means including the enzymatic dehydrogenation of lignin model compounds, the probable presence of a substantial proportion of biphenyl-linked units.

Pew is currently engaged in studies of the lignin macromolecule obtained from finely ground spruce by cellulytic enzyme action. The lignin is degraded by acidolysis in aqueous dioxane combined with hydrogenolysis over palladium-carbon, as a means of cleaving the macromolecule into smaller fragments that may yield clues to the original structure. He is also continuing his studies of simple model phenol compounds by subjecting them to enzymatic dehydrogenation as another means of getting clues to the nature of lignin linkages.

**John C. Pew was appointed to head pioneering unit in his specialty, lignin chemistry.**

Apart from the fundamental work being done by Pew's group, other FPL chemists are engaged in applied research aimed at converting the lignin in spent sulfate pulping liquors into useful chemicals. These liquors are available for commercial processing at pulp mills, some of which now burn as much as 2,000 tons a day. By heating the liquors with alkali, 60 to 70 percent of the lignin can be converted to a mixture of guaiacols, catechols, and other phenols potentially valuable for industrial products such as plastics, glues, and pharmaceuticals.

A reliable chromatographic method of analyzing the chemicals quantitatively as well as qualitatively is being sought. Also under investigation are processing conditions, such as reaction rates and the temperatures, cooking times, and alkalinity and sulfidity conditions most suitable for processing the liquors into useful chemicals.

William Connors, lignin chemist, using chromatographic column to separate lignin intermediates.

## Carbohydrate Research

Research on the complex carbohydrates comprising the cellulosic portion of wood and on their conversion to fiber and chemical products was highlighted during 1963 by application of the newer techniques of conformational (shape) analysis to the relationship between the spatial structure of a carbohydrate molecule and its rate of acid hydrolysis. Experimental proof was obtained of the validity of certain predictions made under this hypothesis. In an analogous manner, it was found that the nature, number, and location of substituent groups play an equally important role in the future conversion of wood sugars to furan derivatives. Such information sheds light on the basic mechanism of chemical reactions and can have highly practical applications for expanding the utilization of wood as a chemical raw material.

Research aimed at developing more precise methods for the isolation, identification, and analysis of the various carbohydrate constituents of wood hemicellulose centered on the xylose-containing polymers of aspen, especially those containing glucuronic acid. Work is under way to obtain substantial quantities of these acidic polymers in the chemically pure state for use as primary standards. A method based on the use of strongly acidic ion exchange resins has been tested and appears promising. The object is to develop analytical techniques of general usefulness to chemists in the pulp and paper and other wood-using industries where sugar-containing byproducts are available in quantity.

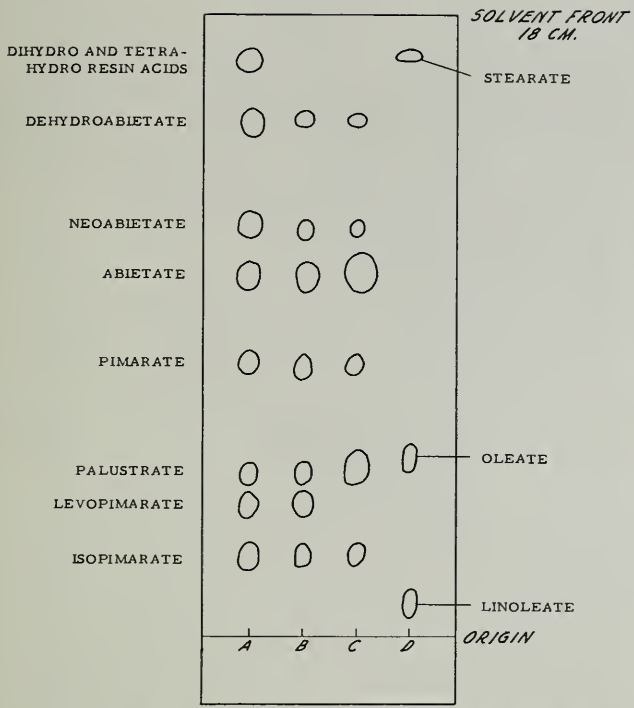
The aging characteristics of paper are the subject of a new study that was begun by a recipient of a Weyerhaeuser Foundation fellowship. A heating chamber in which temperature is controlled to within ±0.1° C. was designed and proved out for use in the study, and thermal degradation experiments are under way on several types of papers.

## Extractives of Bark, Wood

The commercial utility of extractives obtained from bark has been limited by lack of knowledge of their chemistry. Those from wood are commercially important chiefly for naval stores and tall oil. FPL research in this area is centered on fundamental studies of bark extractives and the development of rapid quantitative methods for analyzing tall oil, wood resin, oleoresin, and related mixtures of natural products.

During 1963, continued progress was made in the FPL's fundamental research program on bark extractives. The benzene extracts of pine barks were characterized further. Among many other components, these extracts contain new and unusual triterpenes. The sterols were characterized and found to consist of a mixture of a dozen compounds, mostly representing various stages in the biosynthesis and degradation of $\beta$-sitosterol, the major sterol in pine bark. The benzene extract of lodgepole pine bark yielded a total of 46 different compounds, including a number of interesting new diterpenes. Some 60 compounds have been isolated so far from the benzene extract of jack pine.

In cooperative research with the Pulp Chemicals Association, an exceptionally efficient method was developed for separating the nine main components of




**Thin-layer chromatography, as developed by FPL chemists, produced this separation of methyl esters of fatty and resin acids. Scale at bottom indicates standard known mixtures of, *A*, resin acid methyl esters and, *D*, fatty acid methyl esters used in identifying unknowns separated from, *B*, resin acids of oleoresin and, *C*, resin acids from gum rosin.**

rosin. This method is one of many successful applications of thin-layer chromatography recently evolved by FPL chemists (see 1962 Annual Report). Other analytical methods were also developed, including a gas chromatographic method which can be used directly on mixtures of resin and fatty acids.

A promising chemical method of distinguishing between eastern and western white pine wood is under development. It consists of a rapid paper chromatographic test of the acetone extract of the wood.

### Biochemical Study of Chip Storage

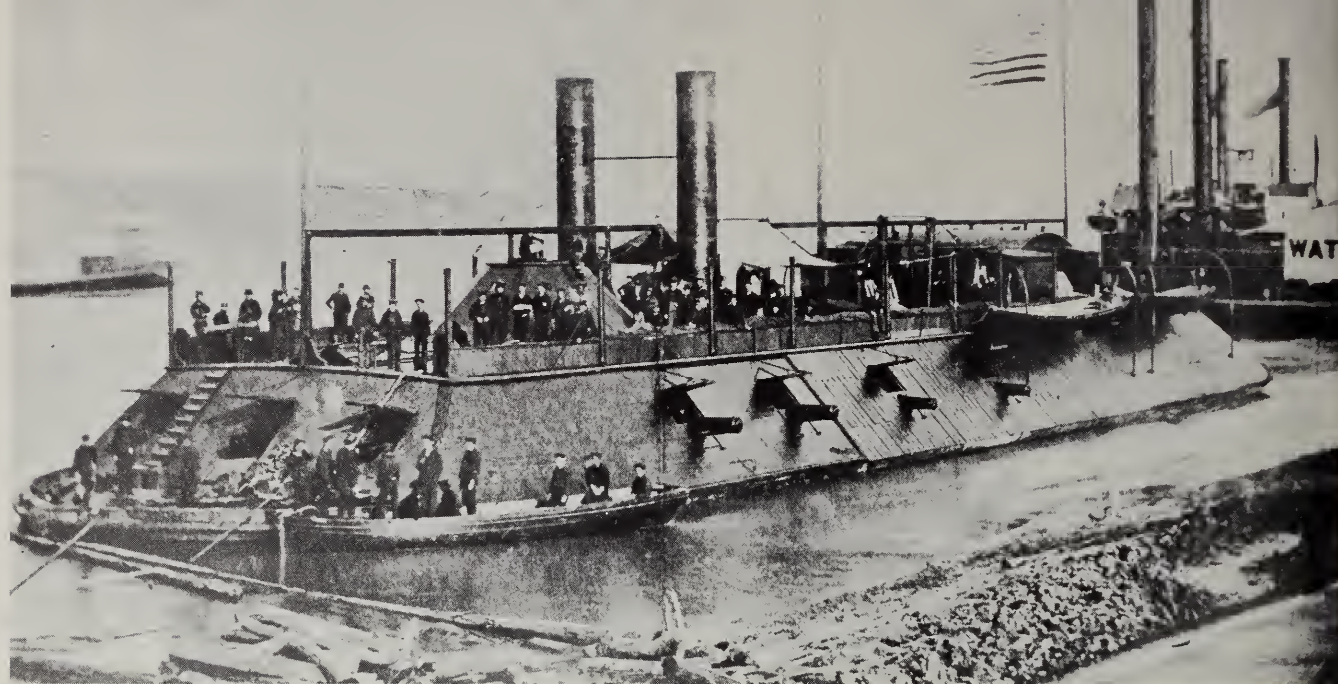
The rapidly spreading industrial practice of storing pulpwood in chip form rather than logs has focused attention upon chemical changes occurring in the wood. Research was begun in 1963 on this problem in cooperation with the Scott Paper Co. and the Northeastern Forest Experiment Station. A pile of chips at the company's mill in Waterville, Me., will be used for the studies, which will be paralleled by laboratory studies on pathological and biochemical factors involved in the deterioration. FPL chemists, biochemists, and pathologists will work closely with the firm's research staff.

**Dr. Harold Tarkow scrutinizes aged wood specimens used in surface stabilization experiments.**

### Physical Chemistry

The physical phenomenon of swelling and shrinking that occurs in wood as moisture leaves or enters the cell-wall structure has long been studied by chemists with the object of controlling or preventing it. Conventional coatings and films afford temporary protection, slowing the entry—and exit—of moisture. Chemical treatments that modify the moisture-attracting constituents in wood are effective stabilizers but affect some mechanical properties adversely and are costly. Socalled "bulking" treatments with chemicals that are deposited in the swollen cell-wall structure of green wood prevent shrinkage as the wood dries but again are costly, add weight, and may impair properties, notably toughness.

In current research at FPL on the problem of dimensional stabilization, modification of the surface regions only is being tried. One object is to improve the ability of the wood surface to retain paint and other finishes. Treatment to a depth of 1/32 or 1/16 inch with phenol resin-forming chemicals is under study. A stabilization gradient is established, normal swelling of the surface being reduced as much as 40 to 60 percent. The species of wood used appears to affect the gradient. Indications are that moisture is absorbed




**Plans to raise Union gunboat U.S.S. Cairo, sunk by Confederate torpedo in Yazoo River near Vicksburg, Mississippi, in 1862, include treatment of wood hull with PEG.**

much more slowly into the interior of surface-treated wood. Radiation effects on surface-stabilized boards coated with clear polyurethane finish are being studied.

Among chemicals capable of reducing markedly the shrinkage of green wood by bulking action in the fiber walls is polyethylene glycol (PEG) (see 1962 Annual Report). The chemical readily diffuses into the fine capillary structure of wood, and has been shown to be effective with gunstocks, woodenware, art carvings, and the like. FPL chemists have given guidance in the use of PEG to protect relics and other objects from deterioration. Among the latest of these is a Civil War gunboat believed to be the first ever sunk by an electrically activated mine.

The armored Union gunboat Cairo sank in the Yazoo river north of Vicksburg, Miss., in 1862. A few years ago divers located it, and since then plans have been made to raise it in 1964 for historical purposes. Meanwhile, wooden gun carriages, furniture, guns, and other objects have been brought ashore. An FPL chemist was consulted on the treatment of these objects with PEG, as well as on the possibilities of similarly treating the vessel's hull and superstructure to prevent deterioration as the water-logged wood dries.

Experiments have also been continued with PEG at molecular weights up to 9,000. Although solutions with such large molecules are viscous, it was found that treatment and drying at elevated temperatures reduce viscosity sufficiently to permit penetration. Substantial stabilization results from such treatment even with PEG of a molecular weight of 9,000, which is considerably less hygroscopic than PEG-1,000, with which the experiments were begun some years ago.

### Charcoal Quality Control

An electrical resistance method of assaying charcoal for quality appears feasible as a result of FPL experiments that establish a relationship between resistance and volatiles content. In making charcoal, progressive operators strive for a volatiles content of about 20 percent. Higher content means objectionably smoky charcoal; lower content, excessive loss of charcoal volume in manufacture. The more volatiles in charcoal, the lower its electrical resistance. This finding is expected to prove useful to charcoal manufacturers as a quality control tool.

### Thin-Layer Chromatography

The versatility of thin-layer chromatography (see 1962 Annual Report) was further broadened during 1963 and placed on a quantitative basis for analysis of many chemical components and derivatives of wood, such as extractives, flavonoids, lignin intermediates, and tall oil constituents. The broad flexibility of this analytical tool attracted much attention at a national meeting of the American Chemical Society.

**As a possible precursor of tomorrow's housing, FPL's "sandwich" unit, consisting of floor, wall, and roof panels with paper honeycomb cores glued to plywood, hardboard, or metal facings, evokes keen interest among visitors. Here delegates to the 1963 convention of the National Federation of Women's Clubs at Milwaukee, Wis., are guided through the unit.**

# INFORMATION ACTIVITIES

The many-sided task of bringing information about wood and its products to those in need of it is a major FPL function that imposes heavy requirements upon the staff and facilities. Events of the year 1963 clearly reflect the constantly expanding demand for such information from industry, Government agencies, research and educational institutions, and the wood-using public. Whether for an international conference of scientists or answering a letter from a homeowner with a maintenance problem, the requirement is essentially the same—the passing on of reliable information.

In all, 81 publications were issued during 1963. The full list is appended to this report. Included were 50 technical and trade journal articles, 8 FPL Research Papers, 21 FPL Research Notes, 1 USDA Technical Bulletin, and the 1962 Annual Report.

In addition to the formal technical publications, 84 news stories were prepared and released. These ranged in content from spot news announcements to feature material with illustrations and summary reports of scientific and technical conferences for technical and scientific journals as well as mass media in all parts of the world.

Visitors comprise one of FPL's most direct and advantageous means of exchanging information—and the exchange is not all one way by any means. Formal meetings with scientists from other laboratories in this country as well as foreign lands offered unusually great opportunity during 1963 for exchange of research data, thoughts, experiences, conclusions, and opinions, as noted elsewhere in this report. Likewise, industry conferences helped keep staff members more fully abreast of current developments and research needs.

Among the 11,274 visitors of all categories who came to FPL in 1963, 3,583 consulted with staff members. Both totals were up appreciably from the year before, when they were 10,686 and 3,317, respectively. Forty-six States, 2 United States Territories, and 54 foreign Nations were represented; 302 visitors came from abroad.

Casual visitors included groups from schools and industrial and professional organizations as well as vacationers passing through.

The following professional and industry organizations and special groups visited FPL in 1963:

Annual meeting, American Society for Testing and Materials (ASTM), Committee D-7 on Wood, January 28–30.

ASTM Committee D-10 on Packaging, April 24–26.

Western Woods Technical Committee (representing industry cooperating in western timber quality survey) April 23–24 and again October 3–4.

Pulp Chemicals Research Committee (industry) May 29.

Industry meeting on fire-retardant-treated wood, June 11–12.

National Wood Pallet Clinic, June 24–26.

Executive Committee, American Wood-Preservers' Association, July 16–17.

Conference on lumber moisture content, West Coast Lumber Manufacturers Association, July 29–30.

ASTM Task Group on Stacking, Committee D-10 on Packaging, August 28.

Section 41, International Union of Forest Research Organizations, September 11–13.

Fifth Conference on Wood Technology, United Nations Food and Agriculture Organization, September 16–27.

Symposium on Nondestructive Testing, October 7–9.

Special Committee on Technical Studies, National Lumber Manufacturers Association, October 9–11.

Iowa Association of Electric Cooperatives, October 29.

**Information and help given a Pulp and Paper Productivity Team of businessmen from the Republic of China (Taiwan) in 1963 won this award from the Agency for International Development, U.S. Department of State. Hanging it on an FPL wall are Director Edward G. Locke and G. H. Chidester, chief of the Division of Wood Fiber Products Research.**


American Paper and Pulp Association, Advisory Committee to FPL, November 14–15.

Group Conference, Pulp Chemicals Association, November 21.

Study Committee on Span Table Groups, National Lumber Manufacturers Association, December 3.

### Scientific and Technical Meetings

Besides extensive participation in the IUFRO and FAO Conferences held at FPL, staff members delivered 90 research and technical papers at international, national, and regional meetings of scientific, technical, and industry groups.

Director Locke spoke to the annual meeting of the Ohio Forestry Association January 25 at Columbus, Ohio; the annual meeting of the Tri-County Forestry Development Association at Wartburg, Tenn., April 5; the Golden Gate Section, Technical Association of the Pulp and Paper Industry, May 14 at Berkeley, Calif., where he delivered the R. M. True Memorial Lecture; the Wisconsin Governor's Conference on Research and Industrial Development, May 23; the Mid-South Section, Forest Products Research Society, New Orleans, October 14; and the Fifth American Forest Congress sponsored by the American Forestry Association in Washington, D. C., October 29.

Dr. Richard F. Blomquist delivered the Marburg Lecture to the American Society for Testing and Materials at Atlantic City, N. J., on the subject of adhesives. Dr. Theodore C. Scheffer addressed an international conference on wood preservation at Freiburg, Germany.

Six staff members presented papers at the annual meeting of the Technical Association of the Pulp and Paper Industry in New York City. Staff members also participated in a TAPPI Forest Biology Conference in Mobile, Ala., a Dissolving Pulp Conference in Montreal, Canada, an Alkaline Pulping Conference in Green Bay, Wis., and a Conference on Fiberboard in New Orleans, La.

Four members participated in the national meeting of the American Chemical Society. Others gave papers at ACS Symposiums on Chemistry of Food Packaging in New York City, on Weatherability of Wood in Los Angeles, Calif., and on Thermal Analysis of High Polymers in New York City.

Five papers were presented to the annual meeting of the Forest Products Research Society in New Orleans and others at meetings of the Southeastern, Midwest, and Mid-South Sections of FPRS. Two papers were given at the Society of American Foresters annual meeting in Boston and two to the American Wood-Preservers' Association in Cincinnati.

A series of lectures was given by G. H. Chidester, chief of FPL's Division of Wood Fiber Products Re-

search, to the Mexican Technical Association of the Paper and Cellulose Industries in Mexico City, on the subject, "The Use of Tropical Woods in Pulp Making."

Other organizations to which papers were presented included the FAO Plywood Consultation in Rome, an International Symposium on Humidity and Moisture in Washington, D. C., the Society for Experimental Stress Analysis in Boston, the Building Research Institute in Washington, D. C., the Society for Nondestructive Testing in Cleveland, Ohio, the National Academy of Sciences in Washington, D. C., the Gordon Research Conferences, the Society for Economic Botany, the Plant Phenolics Group of North America, the Tenth Sagamore Ordnance Materials Research Conference at Syracuse, N. Y., and an Auburn University Forestry Forum.

Industry groups addressed by staff members included the Southern Pine Association annual meeting in New Orleans; a joint meeting of seven Western Dry Kiln Clubs in Portland, Oreg.; a Pacific Northwest Wood Pole Conference; the Hardwood Dimension Manufacturers Association in New Orleans; the Molded Fiber Products Institute in St. Charles, Ill.; the Alabama Forest Products Association in Birmingham; a Time–Life Magazine Round Table on Engineered Use of Wood in Tomorrow's House; the Western Association of State Highway Officials in Denver, Colo.; a Joint Industry Advisory Committee on Roof Trusses in East Lansing, Mich., the National Wooden Pallet Manufacturers Association in New Orleans and a Western Pallet Users Conference in Los Angeles, an Action for Aspen Conference called by the Colorado Division of Resource and Community Development and Colorado State University at Fort Collins, the Northeastern Ohio and Wisconsin chapters of the Society of Packaging and Handling Engineers, in Pittsburgh and Milwaukee, respectively; and an Industrial Packaging Short Course at Purdue University, Lafayette, Ind.

### Educational Activities

Dr. I. B. Sachs returned from a year's study of advanced electron microscopy at the University of Munich, Germany—the first Forest Service employee to receive such training under Public Law 85–807. Dr. Catherine Duncan, FPL pathologist, went to Zurich, Switzerland, to conduct advanced studies in her field under the same law. A National Science Foundation grant will enable her to extend her stay there another 5 months to complete her study.

A three-pronged educational program designed for both undergraduate and graduate students was continued during 1963. Summer laboratory research assignments were provided 18 undergraduates from 12 colleges and universities in all parts of the United States, who were selected from more than 75 applicants.

Seven graduate students of the University of Wisconsin were employed at FPL on research related to the requirements for three Ph.D. and four master's degrees. Fields of research were forest products technology, bacteriology, pathology, and structural engineering.

Two of nine graduate students supported at as many universities with Whitten Act cooperative aid funds completed studies during 1963. One, on machining of wood with lasers and water jets, was done at the University of Michigan. The other, on growth-quality relations affecting lodgepole pine, was done at Colorado State University.

The other seven were in progress at the University of California, Berkeley; University of Idaho, Moscow; University of Minnesota, St. Paul; Oregon State University, Corvallis; Purdue University, Lafayette, Ind.; New York State College of Forestry at Syracuse University; and the University of Wisconsin.

The Laboratory was visited in April by the senior forestry class of Iowa State University, Ames; in June by a group of wood engineering students at Syracuse University; and in July by a group of wood technology students at the University of Michigan.

### Demonstrations, Clinics

One of the largest groups ever to attend a kiln drying demonstration since they were begun in 1919 for industry enrolled in the 87th, held at FPL March 25 to April 5. Forty-two men from 15 States and 4 foreign countries included kiln operators, plant managers, lumber inspectors, wood technologists, and others with technical or business interests in seasoning. Some 30 companies sent employees.

FPL staff members conducted seven sawmill clinics during the year. Three were held in Minnesota, two in cooperation with the Northern Hardwood and Pine Association, and one with the Minnesota State Extension Forester. One was held in Wisconsin, in cooperation with the State Conservation Department. Three were held in Alaska in cooperation wtih Region 10 of the Forest Service.

### Educational Exhibits

To help industry visualize more clearly how to apply research results, FPL exhibits prototype applications at meetings of business and industry throughout the Nation.

In April, 1963, an exhibit featuring southern pine plywood and particle board, the advantages of water-repellent preservatives on house siding, and good painting practice was shown at the Southern Pine Machinery Show in New Orleans, La.; the Southern Forestry Conference of the Forest Farmers Association in April at Edgewater Park, Miss.; and with some modification, at a Conference on Expanded Uses of

Georgia's Forestry Resources at Athens in October. The same exhibit was also on display at the meeting of the Mid-South Section of the Forest Products Research Society in Miami in December.

At a Wisconsin Governor's Conference on Resource Development at Green Lake, Wis., in May, an exhibit featured the use of polyethylene glycol to curb swelling and shrinking of wood, paper overlays to improve paint performance on house siding, the FPL's solar dryer, and Slicewood, an FPL product thick enough for use as boards but cut by slicing rather than conventional sawing.

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